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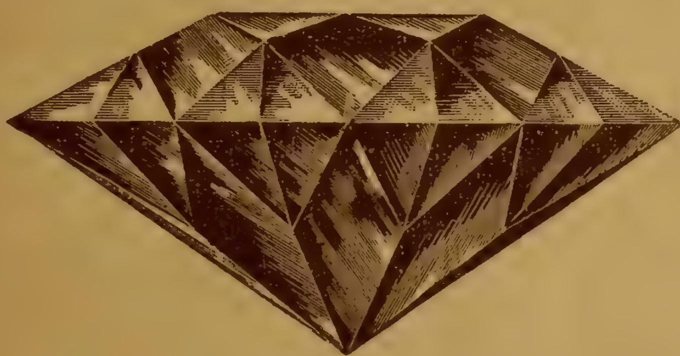
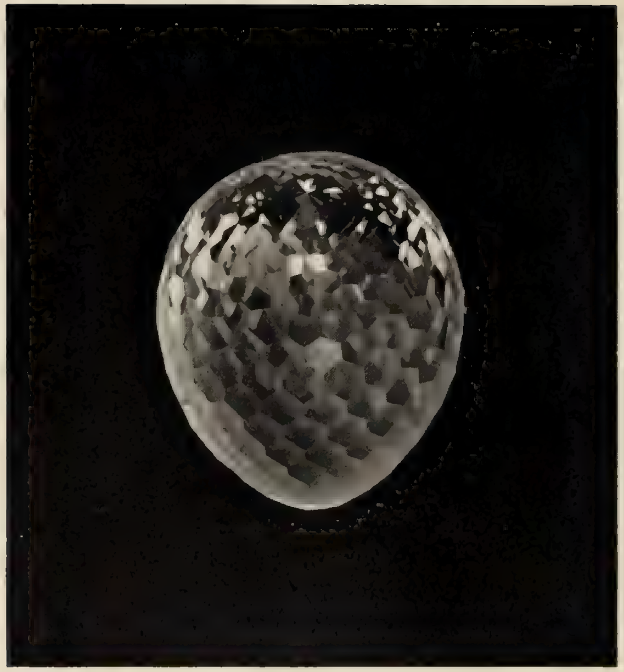
THE AMERICAN MUSEUM OF NATURAL HISTORY

THE ART OF THE LAPIDARY



By HERBERT P. WHITLOCK

GUIDE LEAFLET SERIES No. 65 DECEMBER, 1926



With its 444 perfectly proportioned facets this blue Topaz is a marvelous expression of the art of the lapidary. (Case VI)

THE ART OF THE LAPIDARY

BY

HERBERT P. WHITLOCK

Curator of Mineralogy

GUIDE LEAFLET No. 65

THE AMERICAN MUSEUM OF NATURAL HISTORY

NEW YORK, DECEMBER, 1926

"And they were stronger hands than mine
That digged the Ruby from the earth
More cunning brains that made it worth
The large desire of a King."

—Rudyard Kipling

The Art of the Lapidary

INTRODUCTION

Although a gem mineral in the rough always exhibits certain qualities, which, to a discerning eye, give promise of its possibilities as a gem, it is through the shaping and facetting of these bits of mineral that their real charm is developed. Gem stones are, in general, cut

1.—To bring out beauties of color.

2.—To adapt them to jewelry forms.

3.—To develop the scintillating reflections from the interior of the stone by making use of the principles of refraction of light.

The first two of these considerations are too obvious to require more than a word of explanation. The surface of a transparent uncut gem stone may be compared to the surface of a body of water rendered rough and broken by waves and ripples. It is only when such a surface has been rendered smooth that we are enabled to look down into the depths below and see to best advantage its color. The stones which embellish a piece of jewelry must have a regularity of outline and a symmetry in the disposal of their planes and angles in order to best please the eye.

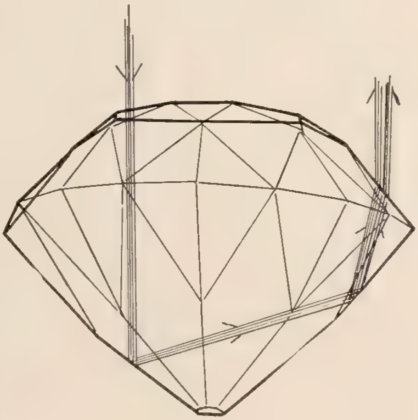


Figure 1

The third reason for the cutting of planes or facets on transparent gem stones needs rather more explanation. We have no doubt many times had occasion to admire the brilliant flashes of light reflected back from the interior of a diamond without realizing how this effect was produced, indeed the reason why a diamond glistens is to most of us a deep mystery. When we put a spoon in a glass of water and hold it above the level of the eye we can see a reflection of the submerged part of the spoon from the under side of the surface of the water which acts as a mirror. Now the light that falls on the upper surface of a correctly cut diamond is reflected back to the eye from the smooth *under* surfaces of the stone in just the same way that the spoon is reflected from the surface of the water in the glass. In figure 1 the paths traversed by some of these rays of light are shown, and it will be seen that they are reflected from the angular sides of the diamond in much the same way that a billiard ball is deflected from

the cushions of a billard table. It is important that the facets should have the correct inclination to one another in order that no light should "leak out" from the under side of the stone, and it is here that the lapidary, that is the person who cuts the stone, must take into account its *index of refraction.* By this we mean the amount of bending that light undergoes when it enters obliquely one substance such as water or diamond from another such as air. Because the refraction of diamond is so high, light having passed through it, must "hit" a surface from the inside much more squarely than would be the case with another substance, such as glass, in order to pass back into air. To insure that all the light that falls on the upper surface of a cut diamond shall be reflectedback we have only to proportion the stone so that the facets of the under side will have

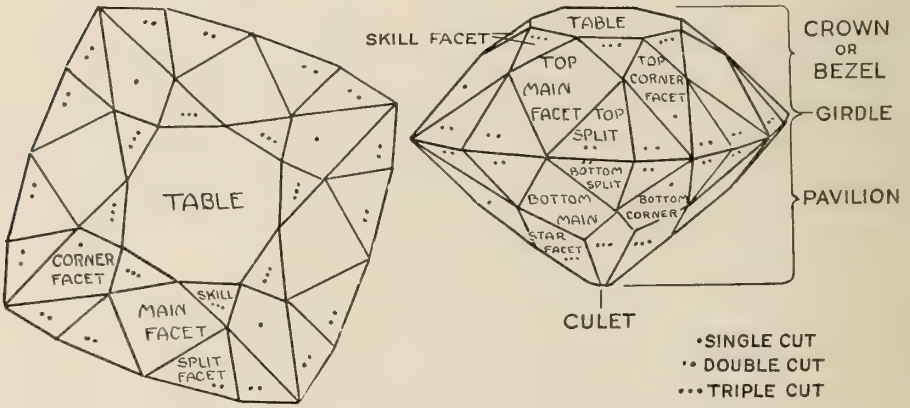


Figure 2

the proper inclination and our diamond will glisten like a star. But a diamond does something more to light than merely reflect it back, it also tends to split up the white light into the colors of the spectrum, so that mixed with the brilliant flashes of white light we also have gleams of the all colors of the rainbow sent back to the eye from our cut stone, which is very properly called a brilliant.

The upper part of a brilliant is called the *crown* or *bezel* and the lower part is known as the *pavilion,* the line separating the crown from the pavilion and which marks the widest part of the stone is the *girdle.* The size of the girdle constitutes the *spread* of the stone and the crown and pavilion taken together constitute its *depth.* There are also special names given to the various kinds of facets and these are given in diagram in Figure 2.

HOW GEMS ARE CUT

When we come to consider the methods and tools of gem cutting, we encounter a sharply defined boundry between these methods and tools as applied to the cutting of diamonds and those used in the fashioning of other and softer gems. This difference of treatment is, imposed in the case of diamond by the special difficulty to be met in grinding and polishing facets on such an exceedingly hard substance.

We will then begin our little excursion into the side of gem knowledge that deals with the way gem stones are treated at the hands of the lapidary by following a diamond on its journey from the mine to the jeweler and seeing for ourselves just what happens to it. When the diamonds are taken out of the mine, not by any means all of them are clear and colorless, as self respecting diamonds should be; indeed only about 25 per cent of the stones found are without some faint color. Of the remainder about one third are of a light shade of violet, yellow or brown, and are known as "off color" stones. The remainder roughly one half of the total find, are more or less deeply colored and are consequently of no value for jewelry although still usable as diamond dust for cutting and polishing and also for the cutting edges or facings for rock drills. So we find that at the beginning of its travels the diamond is introduced to the sorter. The sorter is a kind of a super-expert on diamonds whose eye has been trained through years of practice to detect the slightest variations in the color of diamonds, and to find flaws in stones with an ease which is little less than uncanny. Safeguarded behind a heavy metal screen, the diamond appraiser sits with a pile of rough stones before him, judging each stone and assigning it to its proper heap.

The first consideration in sorting diamonds is the adaptability of the stone for cutting. Let us assume that the stone whose travels we are following is sorted into the grade known as "close goods" comprising, complete, flawless crystals from which fair-sized brilliants can be cut, to use the trade term, "made." These usually have eight sides or faces, triangular in shape. Next comes a resorting of the "close goods" into eight grades, ranging from blue-white, which comprises the stones of finest quality, to yellow and brown crystals, which are so badly off-color as to be unfit for gems. If our stone has passed the critical test of the sorter and has been placed in one of the higher grades, it is weighed wrapped up in a parcel with others of its kind, a price per carat is assigned to it, and it is sold to a diamond dealer, and ultimately finds its way to the workshop of the diamond polisher. Here at the hands of a highly skilled workman, it is destined to be turned into a gem fit to grace beauty or proclaim opulence.

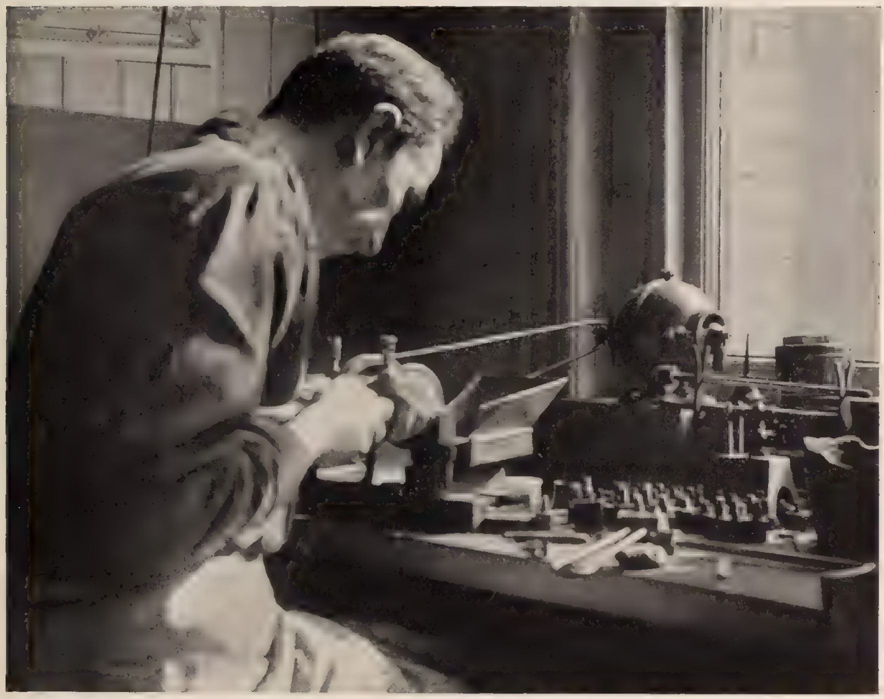
Much of this work is done in Holland and especially in Amsterdam which since the Fifteenth Century has been famous for this industry, which is in reality an art, but there are, nevertheless, a number of shops in operation in New York and in other American Cities. Like many other operators who depend for their success on a high degree of manual skill, the diamond cutter uses few tools, and these are relatively primitive and have changed but little since the days of Louis de Bequem, who cut

Like a skilled surgeon the diamond lapidary performs the delicate operation which is known as "slitting." Just the right amount of the stone, no more and no less, must be split away. The intent expression on the face of the operator bears witness to the momentous effect of the slight blow he is about to strike on the steel knife edge which he holds in his left hand.

diamonds as early as 1475. The lapidary trained in his art depends, like the violin player on the delicacy of his touch, and like the painter on the accuracy of his eye. In general he does not employ complex mechanical devices to aid him in his difficult task.

The surface irregularities, which are often present on diamonds of even the highest quality must be first split away from the stone, which breaks naturally along smooth, even surfaces parallel to the natural faces of an octahedron. Superficial flaws, that is incipient cracks, and

dark patches or "carbons" must also be eliminated in this way. Sometimes these occur deep in the center of an otherwise perfect crystal, in which case the diamond is divided *through* the imperfection and made into two or more cut stones. To accomplish this cleavage, which is known as "slitting," our diamond is firmly cemented to the end of a wooden stick which, in turn, is supported firmly in an upright position by wedging it



Even the refuse from this operation is valuable and must be saved. As the lapidary rough-shapes his diamonds, rubbing or "bruting" the one on the end of the long stick which he holds under his right arm, against the other on the rapidly turning spindle which is driven by the belt, the dust and fine fragments fall into the little box shown in the centre of the picture. Only the protruding end of the stick is visible in the illustration.

into a hole in the working bench. The diamond lapidary now makes a deep scratch in just the right place upon the surface of the diamond crystal, using for this purpose the sharp corner of a diamond fragment. A knife edge is then held in the correct position on the scratch, and a sharp blow with a light tool struck on the back of the knife edge suffices to remove the undesirable flake, leaving the surface bright and very smooth.

Sometimes, when the stone is large, it is of advantage to saw it into two or more pieces so as to save as much as possible of the weight in cut diamonds. This is accomplished with a thin disk of bronze, about four inches in diameter, revolving very rapidly and having its edge charged with diamond dust at the beginning of the sawing. As the saw bites into

The tools of the diamond lapidary's art are very simple. The little metal cut or "dop," in which the diamond is being placed, as well as the wooden holder which carries it, are of exactly the same shape as those used by the diamond cutters of a hundred years ago.

the stone, it keeps recharging itself with the diamond sawdust. It takes many hours for this little "buzz saw" to eat its way through half an inch of diamond, but the finished product is so valuable that a day or so of labor makes little impression on the cost sheet.

The rough shaping of the diamond is done through an operation called "bruting," which consists of wearing away the corners by rubbing

one stone against another. Formerly this was strictly a manual process, the two diamonds being mounted on sticks held in either hand by the lapidary. Even into the ancient and conservative art of diamond cutting, however, some mechanical improvements have made their way, and now in most of the shops a rapidly twirling spindle takes the place of one of the hand sticks. The remaining stick has grown in length to suit the modern method. It is now about two feet long and can be firmly grasped

The actual cutting of the facets on the diamond, known as "polishing," calls for the highest expression of the diamond lapidary's art. The stems of the "dops," which bear the diamonds, must be adjusted in the "tongs" with fine nicety. Here again the form of the tools has not changed in a century. The iron "tongs," the wheel and its spindle (shown in the centre of this picture), even the metal pegs against which the tongs are kept in place on the wheel, are the same as those used in Amsterdam and Antwerp in 1821.

with both hands and held in a rest so that the diamond it bears at its end can be rubbed against its fellow, which is spinning in front of it.

Having in this manner rough-shaped our diamond, we now come to the finishing operation, the producing of the facets which give brilliancy and sparkle to it, an operation which is technically known as polishing. The holder of the stone during the polishing consists of a small metal cup on a long stem, which is called a "dop" and much resembles a tulip,

which famous Dutch flower may have suggested its shape. A solder composed of one part tin and three parts lead is placed in the dop and heated until soft. The diamond is then embedded in the solder with the portion of the stone on which the desired facets are to be cut placed uppermost. When the diamond has been properly adjusted in the dop, it is plunged in cold water to cool and harden the solder. Such drastic treatment would cause less aristocratic stones promptly to fly to pieces, but not so with the diamond; the high heat conductively of this remarkable mineral permits to to submit to the sudden change of temperature without there resulting in it even the slightest flaw.

The dop is now fastened by means of its stem in a heavy iron arm, called the tongs, in such a way as to bring the position of the facet to be cut exactly undermost when it is placed in contact with the polishing wheel or "skeep." It is here that the skill and training of the diamond cutter is exercised to its fullest, for the tilt or inclination of the various facets, the one to the other depends on the position of the dop in the tongs and on just how much the stem of the former is bent to the one side or to the other.

The "skeep" is made of soft iron and turns horizontally at the rate of about 2500 revolutions a minute. Diamond dust, mixed with olive oil, is fed to this wheel and the diamond is held in contact with it by the weight of the tongs aided by slabs of lead placed upon the latter. Much care has to be taken to keep the skeep perfectly balanced so that it will revolve without the slightest rocking motion, because this would materially interfere with the even smoothness necessary to the production of a finely polished surface. Several hours are required to cut one facet, then the dop is readjusted for another one, or the stone is removed and reset in the dop, and so on until all of the fifty-eight little faces in which lie the secret of the brilliancy of the jewel are produced.

To appreciate the exquisite skill and infinite patience involved in this apparently simple process we have only to look at the gem on our finger sending forth its magical fires, and to note the symmetry and regularity of shape of each of its tiny glittering sides. And when we remember that to produce these rainbow-like rays each must have exactly the right tilt with respect to its neighbors, we realize that a cut diamond is not only a wonderful product of nature but a marvelous work of art.

The cutting of the softer gem stones is not nearly so laborious an undertaking as the cutting of diamonds. Not only is diamond harder than any other substance known, but it is very much harder than the corundum gem stones that follow next after it in hardness. So it is that we find the tools and methods applied to the softer gem stones at once simpler and more highly manual.

The native lapidaries of India and Ceylon have reduced the apparatus of this phase of gem cutting to its lowest terms. Such a native artisan seated on his carpet in the bazaar, turns the stone lap in front of him by the primative means of a bow, the string of which is wrapped around the axis of his stone grinding wheel. By his side is a bowl containing the emery he uses as a grinding medium mixed to the right consistancy with water, and his left hand is the only holder for the gem stone that he is manipulating. This is indeed reducing the tools of gem cutting to an absolute minimum, and emphasizing in a striking way the essentials of this art.

These essentials are then:—

1.—A rapidly revolving wheel, the flat surface of which is of just the proper roughness for retaining the powdered abrasive with which the cutting of the smooth facets of a gem stone is accomplished. This wheel is usually termed a lap.

2.—A holder, corresponding to the dop used in diamond polishing, but in this instance made of wood and resembling in size and shape an old-fashioned pen holder.

3.—An abrasive substance of a greater degree of hardness than the gem stone to be cut which is fed to the lap as a powder mixed with water to a more or less thin paste. For the final polishing the abrasive is fed dry to a wooden or cloth covered lap.

Gem stones are first sawed or "slit" by means of a thin disk of relatively soft metal whose edge is slightly indented with a knife blade for its entire circumference. Diamond dust mixed to a paste with water, is fed to this circular saw, and lodging in the indentations of the circumference constitutes the cutting edge. The process of slitting for colored stones is very much more rapidly accomplished than the corresponding operation for diamonds and, except in the case of valuable gem stones such as rubies and sapphires, no great amount of care is taken to conserve the chips taken off.

After a suitable piece, free from flaws and other blemishes, and of convenient proportions, has been sawed from the crystal or rough fragment of gem material, this piece is usually cemented to the end of a wooden holder for the rough shaping which corresponds to the "blocking out" of a painting. This is done against an emery or carborundum wheel, resembling a small grindstone and revolving on a horizontal axis. If the stone is to be given a "cabochon" or rounded cutting like an opal or a cat's eye, it is finished on this wheel and polished on a similar one of softer material charged with rouge or putty powder. If, however, the stone is to be facetted, the real skill and judgment of the lapidary is

called into play. The rough shaped stone is attached with cement to the blunt end of a wooden holder, called the stick, which is about 8 or 10 inches long and which is pointed at its free end. The position of the stone when fastened to the stick is so chosen that the table facet when cut will be at right angles to the latter and it is embedded in the cement up to the point where the prospective girdle will encircle it.

The grinding lap, which is made of gun metal, copper or lead, depending on the hardness of the stone to be facetted, is mounted so as to revolve in a horizontal plane like the skeep used in polishing diamonds,

Extremely simple are the tools and methods employed by the lapidary working in stones other than diamonds. The wheel or lap, a stick to hold the gem, a notched peg, seen behind his hand and his own supreme manual skill alone suffice him.

and the speed at which its surface travels *against* the stone can be manipulated with great nicety by moving the latter nearer to or farther from the center. Having charged his lap with the appropriate abrasive, emery or corborundum the lapidary now places the stone upon its surface and holding the stick in a vertical position grinds the table facet to its correct proportion with respect to the design of facets which he has in mind.

The next step is to cut the first of the main facets of the crown, which of course necessitates the holding of the stick at just the right angle to the surface of the wheel, and as a rough guide the lapidary is here aided by a device called the "jamb peg" mounted at the side of the lap and pivoted

so as to swing out over it. The jamb peg is shaped somewhat like an elongated peg top and is furnished with a series of shallow indentations at regular intervals from top to bottom, so that by placing the sharpened end of the stick in one of these a constant angle between the stick and the surface of the lap can be maintained. Having cut the first of the main facets of the crown to the right depth, the lapidary now turns the stick through just the right arc of a circle to bring the next facet to bear on the surface of the lap and using the same hole in the jamb peg cuts this also to the correct depth constantly inspecting his work and judging the fine points of inclination and proportion of the facets by eye. But since he can not see what is taking place while the stone is in contact with the lap, he must here depend on a highly developed sense of touch. Just as the finger of a violinist flies unerringly to the precise spot on the neck of his instrument to produce a given note, so the trained touch of the lapidary guiding the stick that holds his gem upon the wheel finds almost by instinct the correct angle for the stone to come in contact with the grinding surface to produce the result he desires.

One after the other the main, split and skill facets are cut and then the stone goes to the polisher who, working in the same way but on a lap having a softer and finer surface, and using a finer abrasive, removes the slight scratches from the facets, polishes them to a finished brilliancy and incidentally corrects any slight irregularity in their proportion. Because of this last consideration it follows that the polisher must be a master in his craft.

The crown or upper half of the stone having thus been completed it is now removed from the stick, cleaned and again mounted in cement, but this time with the lower half exposed on the end of the stick. The process of cutting and polishing is now repeated for the pavilion facets and the stone is finished.

THE FORMS IN WHICH GEMS ARE CUT

THE EVOLUTION OF THE BRILLIANT CUT

The history of gem cutting, insofar as it touches the modern art of the lapidary, may be said to begin with the introduction of diamonds as personal ornaments into Europe about the 15th century. It is perfectly true that precious stones were worn upon the person of men and women at a period which carries us well back into prehistoric times, and it is possible to trace a certain rough fashioning in even the most antique of these. But, aside from the question of whether the early gem artifacts were worn for purely esthetic reasons; or, as is more probable, for charms endowed with a certain occult potency, the fact remains that up to a comparatively late period no attempt was made in shaping a gem to do more than adapt its outline to the form of setting designed for it, and to round off its corners and irregularities so that its color might be seen to the best advantage.

In tracing the development of gem cutting in general, we are led inevitably for a point of departure to the forms first produced in the cutting of diamonds, because these early diamond cuttings impressed their character and symmetry not only upon later developed forms of cutting adapted to diamonds but to the subsequent development of forms of cutting among all the other transparent gem stones.

We have the authority of O. M. Dalton in the Catalogue of Finger Ring in the British Museum for the statement that previous to Louis de Bequem, that is prior to the latter half of the 15th century, four of the eight faces of octahedral diamond crystals were sometimes polished and the stone set with the polished pyramid projecting while the unpolished portion of the stone was imbedded in the setting. The next step in advance of this very obvious and primitive facetting was to brut two diamond crystals together until the operator had worn away one of the points of the octahedron into a square facet, corresponding to a table in the modern brilliant, and similarly worn a smaller facet on the opposite point corresponding to the culet. This earliest of diamond cutting is shown in Figure 3. Frequently the culet was omitted and the table was developed to even a smaller extent than shown. We have reason to believe that this modified point cut persisted at least into the 17th century inasmuch as a ring dating from this period in the British Museum collection is set with a diamond cut in this way.

Aside from the fact that the modified point cutting utilized the maximum spread and a large proportion of the maximum weight of a given stone, the square girdle produced a certain awkwardness which, sub-

sequently led to the modifying of this form by the cutting away of the corner edges both in the crown and the pavilion and the production of an octagonal girdle.

As a finished expression of the diamond cutters art this form of cutting, which is shown in Fig. 4, and which is sometimes called single-

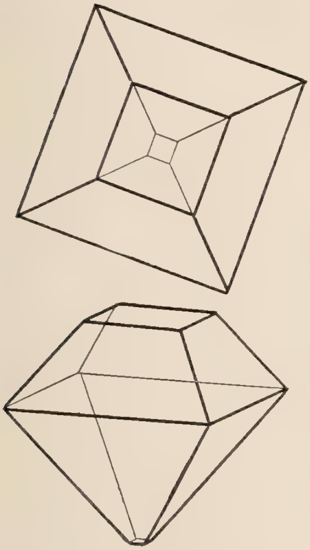


Figure 3

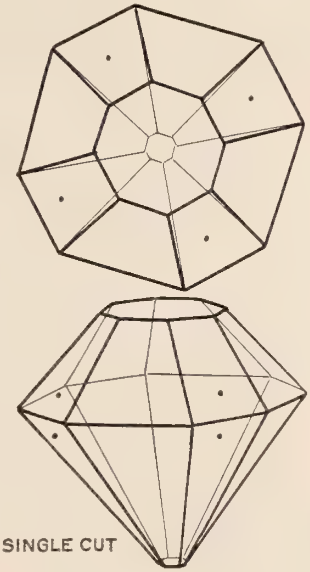


Figure 4

cut, has long been obsolete; it is, however, interesting to note that in the evolution of a modern brilliant cut, the diamond crystal or cleaved piece passes through both of the preceding forms as its initial stages before the split, star and skill facets are produced. It would seem fair then to consider both of these cuttings as old forms of brilliant cut.[1]

About the middle of the 17th century a development of the two previous forms of cutting into what has been variously called the square cut brilliants, single-cut brilliants,[2] or double cut brilliants,[3] took place. The first of these forms, Fig. 5 which we will call the square cut brilliant, retains the original square table of Fig. 3; the top main facet of a single cut starting from the corner of the table making with the single cut an octagonal girdle the corners of which are taken off with the corner facets of a double cut starting from the same point. The main and corner facets are repeated in the pavilion starting from a point on the edge

[1]See W. R. Catelle, The Diamond, Plate V, Figs. 1 and 2.
[2]Emanuel.
[3]Bauer.

corresponding to the corner of the table. This gives a brilliant of 34 facets not without a certain amount of symmetry, particularly in the crown.

The English square-cut brilliant, or old English star-cut brilliant, Fig. 6, is derived as in Fig. 4, and with double cut corner facets developed as in the previous cutting. This gives a brilliant of 30 facets with an octagonal table and a rather more symmetrical grouping of the facets of the crown than any of the preceding cuttings. A somewhat later development of the double cut brilliant is shown in Fig. 7. This is the connect-

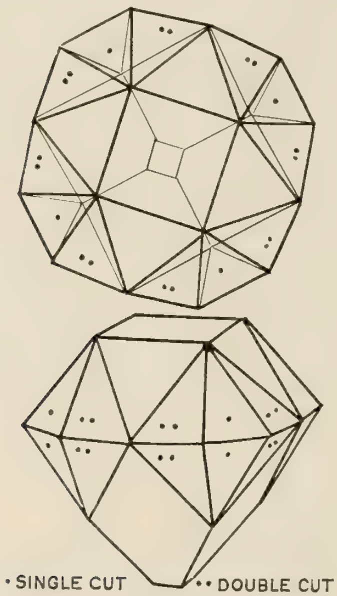


Figure 5

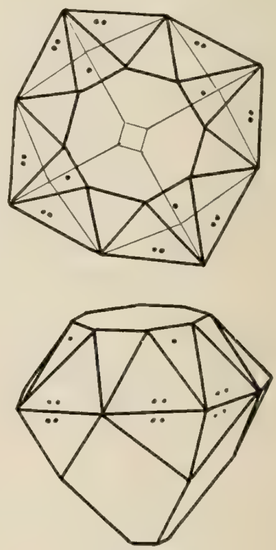


Figure 6

ing link between the single cut brilliant of Fig. 4 and the various forms of the triple cut brilliant which will be presently discussed; the edges between the main facets of the single cut being partly replaced in crown and pavilion each by two corner facets. This gives a brilliant of 50 facets with much the same outline of the girdle as has the Brazilian cut or Old Mine cut (Fig. 9).

What the square-cut brilliants following the lines of the basic octahedron failed to do was accomplished with the introduction of the triple-cut brilliant toward the end of the 17th century and the beginning of cutting for brilliancy and weight rather than for weight alone. Three variations of the triple cut brilliant are of sufficient importance to be here considered.

The English Round Cut Brilliant of which an excellent description with relative proportions is to be found in Emanuel's Diamonds and Precious Stones, was apparently in vogue in England in the middle of the 19th century. This variation of the triple cut brilliant (Fig. 8) differs from the American brilliant of today only in the relative proportions of its essential parts. In it the angles of the octahedron were deviated from to produce a stone of depth rather than spread, the "lumpy" aspect of the cutting being the result of making the diameter of the girdle equal the

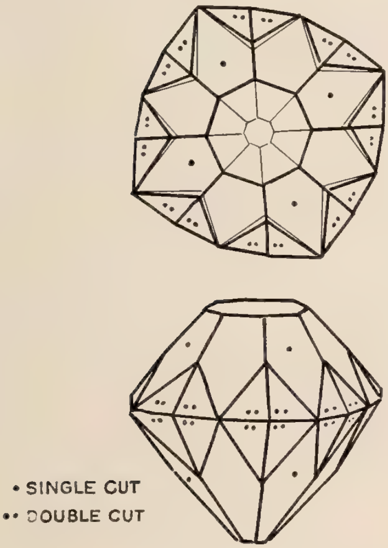


Figure 7

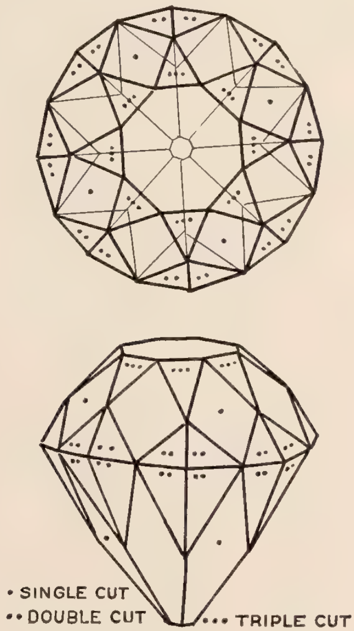


Figure 8

total depth. The number of facets were increased to 58 by the addition of the skill facets in the crown, a change which not only added to the symmetry of the exposed portion of the cutting but increased the surface reflections. The essential innovation, however, lay in the altering of the angles of the crown and pavilion main facets to totally reflect back a large proportion of the light falling directly on the crown, these reflections materially adding to the brilliancy of the cutting. It is evident that the theory of this cutting necessitates rather a high crown with a relatively small table and that some sacrifice is made of the spread of the stone so that for a given weight a stone of relatively small spread but considerable brilliancy is obtained.

The tendency to retain the girdle outline of the old square cut brilliants found expression in the Brazilian cut brilliant or Old Mine cut, which is shown in Fig. 9, and which was very much in vogue during the last century at a period when Brazil was producing most of the world's diamonds. In the example shown, the angles between the main facets of the crown and pavilion approach more nearly in average to the ideal angle (80°-85°) of the modern brilliant than in the English round cut brilliant, where this angle is over rather than under 90°. The result is a

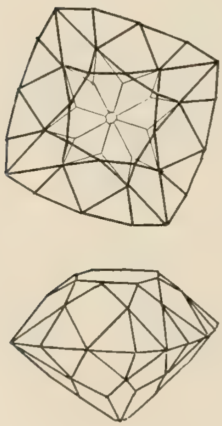


Figure 9

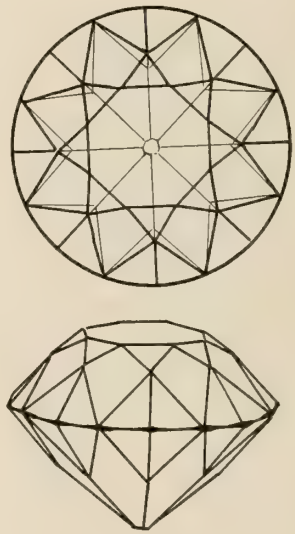


Figure 10

cutting of better because less "lumpy" proportions and one in which thinner stones could be cut to better advantage.

The final stage in the evolution of an ideal brilliant cut takes the form of the American cut brilliant shown in Fig. 10. This cutting combines the most satisfactory angles of the Old Mine cut in a brilliant with a round girdle, and although, undoubtedly some of the weight of the uncut stone is sacrificed to brilliancy and prismatic reflections a considerable spread compared with the weight of the cut stone is reached.

VARIATIONS OF THE BRILLIANT CUT

In tracing the evolution of the brilliant cut from its earliest and most primitive form down to the highly developed brilliant of our own day, we followed, as it were, the main line of evolution leading to the cutting most adaptable to stones of medium weight and general use. It must be

clearly borne in mind, however, that in the course of this development forms of gem cuttings have sprung from the main line of advance at many points, some of these having achieved only a transient popularity in the past, and some representing variations which are still in use for stones adapted to certain settings. To anyone familiar with the great diversity of these variants from the well known brilliant form of cutting, the futility of attempting anything in the nature of a classification will be quite patent. In some instances, as in the case of the table cut, the variation is mainly one of proportion, while in other cases the forms of cutting are combinations of brilliant and step cut. For convenience in arranging the data collected, it has been thought best to roughly divide the varia-

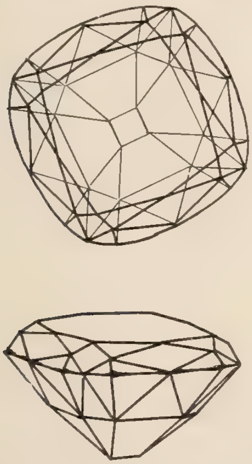


Figure 11

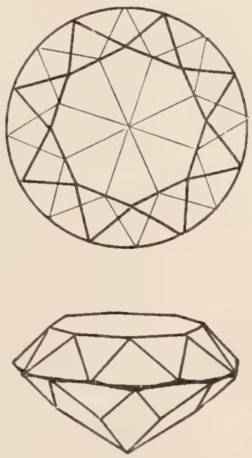


Figure 12

tions of the brilliant into three groups, based partly on the adaptability of the cutting to jewelry forms. Grouped in this way we have:

(a) Cuttings with symmetrical or rounded girdles.

(b) The commoner forms of fancy cuttings.

(c) Unusual forms of fancy cuttings.

The first of these groups include stones adapted to solitare ring settings, for the centers of clusters, and in fact for every form of jewelry setting where a round, square or six-sided stone is required.

Conspicuous among cuttings of this group is the square brilliant, a notable example of which is to be found in the Cullianan IV diamond, shown in Fig. 11. Although of much the same girdle outline as the typical Brazilian cut, exemplified in the Regent diamond, this cutting differs widely in proportion from the older forms; the crown is shallow with a broad table, and a considerable mass of the stone lies below the

girdle. The main facets of the pavilion were doubled, bringing the number of facets up to 66 and giving to the culet end of the stone the appearance of a step cut treatment.

The round double-cut brilliant shown in Fig. 12 and known as the table cut, represents a degree of simplicity of cutting which strongly suggests the old English star-cut brilliant from which it was possibly derived. The table cut has 33 facets and is characterized by a broad spread compared to the depth, and a shallow crown with a broad table. In the example studied for Fig. 12, the proportion of spread to depth was 2 to 1, and the depth of the crown was about one-third the total depth. Thin

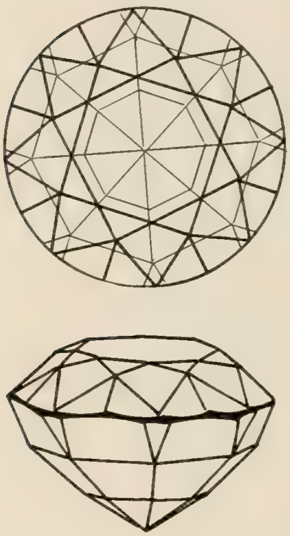


Figure 13

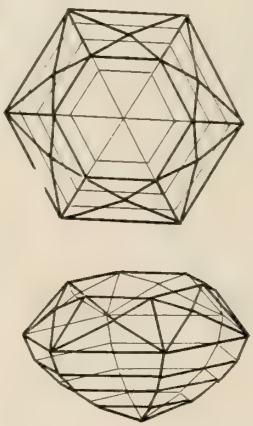


Figure 14

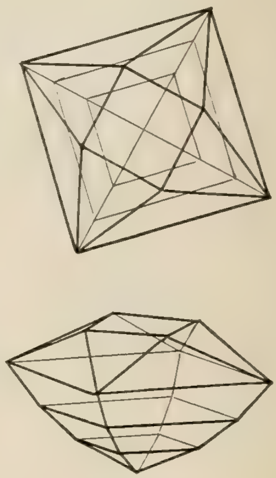


Figure 15

diamonds were formerly made in this cut, which has little or no advantage other than a high proportion of spread to weight

An extremely popular cutting for sapphires, rubies and the deeper colored semipreicous stones is the combination brilliant-step cut. An example, studied from a blue synthetic sapphire, is shown in Fig. 13. This variation of the brilliant has a rather low crown, cut with the conventional 33 facets, and a deep pavilion of three tiers of stepped facets. The girdle-bottom main facets are shaped to the circular girdle by single triangular corner facets, as shown in the figure. For colored stones of high index of refraction the combination cutting is very effective, as it brings out both the fire and the color of the gem, but like all forms involving step cutting, it requires that the proportions and slope of the pavilion facets should be carefully studied.

The six-sided cutting shown in Fig. 14 although formerly used to a limited extent for diamonds, has now almost entirely given way before the various forms of unmodified step cut. This cutting is in reality a variation of step rather than in any sense a form of brilliant cut; it is introduced here, however, because the use of corner facets in the crown allies it to an extent with the latter group. In the example shown in the figure the cutting produced rather a "lumpy" stone in which about one-third of the total depth lay above the girdle. Diamonds made in this cutting are often met with in old-fashioned settings, and there is no doubt that they possess a certain quaint charm; but unless very carefully proportioned much of the brilliancy of the stone is lost.

The French cut brilliant, illustrated in Fig. 15 is principally used for small rubies, emeralds and sapphires when it is necessary to set these in a row for a bar pin or similar piece of jewelry. In this case of "calibre" cutting the square girdles of all of the stones constituting the setting must of course be made exactly the same size. For a small circlet, as in the instance of a diamond encircled by calibre-cut sapphires, the small stones are cut with a girdle which is slightly keystone-shaped to accommodate the curve of the circle. Like the preceding this cutting is closely allied in make to the step cut, being essentially a step cut with star facets in the crown.

In dealing with the great variety of fancy cuttings which are more or less derived from the brilliant cut, the difficulties in the way of arriving at anything approaching an adequate basis of classification are appreciably more than those met with in dealing with the group of cuttings with symmetrical or round girdles. At least in these latter we were guided by the outline of the stone and by the fact that most of the cuttings of this type were designed for setting in solitaire rings or for the centers or encircling elements or clusters. We now come to a group of cuttings of excentric girdle outlines, distorted from the round and with the brilliant cut crown, which alone ties them to the basis from which they are derived, pulled this way and that until the possible shapes producible as fancy cuttings seem endless. Another point of differentiation between this and the group previously discussed, is that in the case of the fancy cuttings the stones are mostly adapted to settings other than rings, and that the cuttings are to a large extent used for the making of stones other than diamonds. A notable exception to both of these latter characterizations is that of the marquise cutting which is used principally for diamonds and is almost universally set as a ring stone. The marquise was introduced as a cutting for diamonds early in the last decade of the XIX century when popular taste in ring stones created a demand for a long narrow cutting intended to be set with the long axis parallel to the finger joints.

A typical example of a marquise cut diamond is to be found in No. VII of the Cullinan cuttings, which weighs about $9\frac{1}{2}$ carats. Fig. 16 was studied from a model of this stone, and represents an average proportion between length and breadth of girdle outline which varies to a very considerable extent in this as in most of the other fancy cuttings. The 58 facets which constitute the "make" of the marquise correspond in relative position, facet for facet, with those of the round brilliant, the obvious distortion in shape of the facets being occasioned by the lengthening of one diameter of the type cutting. The broken arcs which outline the table are rendered more nearly circular by decreasing the size of the skill facets, so that instead of meeting corner to corner around the table their edges with the table are alternated with edges of the top main facets.

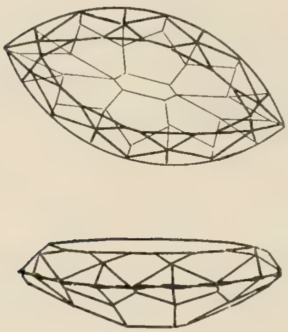


Figure 16

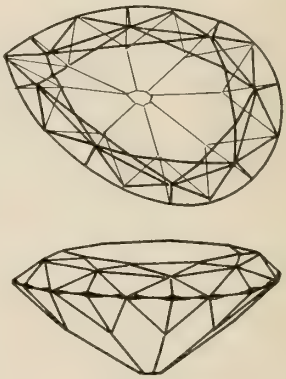


Figure 17

The pendent cut, illustrated in Fig. 17 is used for a great variety of precious and semi-precious stones. The example shown was studied from a model of the No. 111 Cullinan diamond, and may be taken as an average in proportion of length to breadth between the very broad pendent shapes, as exampled in the Cullinan I diamond and the very long slender pendents cut from small chrysoberyls, tourmalines or aquamarines. Whereas in the case of the marquise the variation from the round brilliant was produced by lengthening one diameter symmetrically, so in the pendent cut the variation consists in lengthening one end of a diameter of the type cutting. Pendent cut stones are very rarely, if ever used for ring settings, and although a considerable proportion of the stones cut in this make are diamonds, it is very generally employed for all of the light-colored stones through a very wide range of weight.

Intimately related to the pendent-shaped brilliant is the heart-shaped brilliant, illustrated in Fig. 18. This variation of the type bril-

liant cut might be considered as a pendent-shaped brilliant, with the round end somewhat flattened and with the girdle outline broadened until its length about equaled its breadth. In the present example, which was studied from a model of the No. V Cullinan diamond, the crown is shallow and the table relatively large.

No attempt has been made to work out the difficult problem of the optics of the three foregoing variations of the brilliant. There are so many elements to be considered where not even the girdle outline is a constant that we are led to suspect that the lapidaries and diamond cutters have no guiding rule, but make the stone to get the best advant-

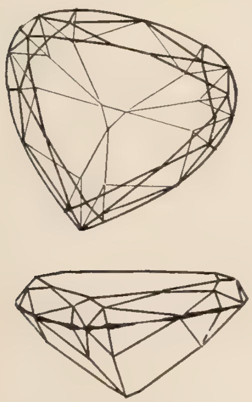


Figure 18

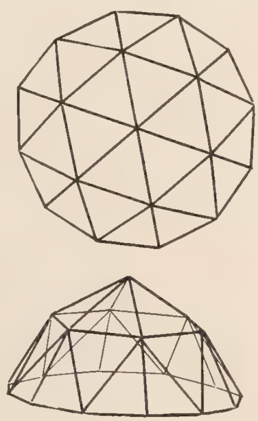


Figure 19

age of weight and spread without considering the angles which give the maximum brilliancy. The three illustrations chosen from the work of so distinguished a lapidary artist as Joseph Asscher, undoubtedly express a very close approximation to ideal proportions for their respective cuttings.

The extremely wide range of forms which are classed by lapidaries are fancy cutting precludes the discussion in a limited space of more than the essentially characteristic variations involving a treatment of the crown facets derived from the brilliant cut. With respect to the pavilion facets these "fancy shapes" have for the most part been given some variation of a step cutting, but even in this there appears to be no set rule and the details of the facetting is largely a matter of individual taste on the part of the lapidaries.

THE ROSE CUT

The "Rose" cut or "Rosette" enjoys a history more ancient, if not more honorable, than the brilliant cut. As far back as the early decades to the 16th century this form of cutting was in vogue for diamonds. It is said that several of the diamonds of the French crown were recut to a rose form by the order of Cardinal Mazarin, an association of names which had led to the tradition that the rose cut was invented by the famous ecclesiastic.

Since the 17th century the rose cut has steadily given place in popularity before the increased luster of each succeeding modification of the brilliant cut, and it is now used only for very small cluster diamonds and for such deep colored stones as Bohemian garnet.

One of the earliest variations of the rose cut is the Holland rose, Fig. 19. In its simplest and probably its oldest form this cutting consisted of only 12 facets above the flat base, arranged in two stepped rows of six each. The rose cut shown in the figure was probably derived from this. the primitive phase, by the addition of 12 facets around the base which correspond to the corner facets of a brilliant cut. The six upper facets constitute the crown and the 18 facets of the lower row are known as the cross facets. As applied to the diamond, much of the light which falls on the facets of the Holland rose in a direction normal to the base is returned to the eye above the base, but owing to the small number of reflections for each pencil of rays the rainbow-like colors which constitute the chief charm of a brilliant cut are lacking.

The Brabant rose, presents the same general arrangement of facets as the Holland rose, but differs from the latter in that the ring of cross facets is steeper and the crown lower. Optically this cutting is not nearly so efficient as the other forms of rose cut, most of the incident rays of light escaping through the base, a fact which probably accounts for its early lapse from popularity. This cutting apparently originated in Antwerp when that city was contending with Amsterdam as a diamond-cutting center and represents an unsuccessful attempt to rival a characteristic Dutch cutting.

Both of the above rose cuts have been slightly varied; as, for instance in the substitution of one instead of two facets in the double cut which takes off the corners of the base, giving to the cut 19 instead of 25 facets. Another variation carries the crown facets of the single cut to the base in a six or eight-sided pyramid, and double cuts each corner. with one facet carried half way up the edge and making the crown facets lozenge shaped. This is known as the cross rose.

The rose recoupee a more elaborate variation of the Holland rose, is shown in Fig. 20. This has twice the number of single cut facets, that is,

24; and because the single cutting is more elaborate, only one double cut facet for each corner is given. This makes a cutting of 37 facets with a 12 sided base. From the point of view of effective brilliancy, the rose recoupee far exceeds the other cuttings of this class, the leakage through the base being relatively small, and in general the light is returned through the crown facets.

The double rose, Fig. 21 is a variation hardly less classic than the Holland rose from which it was derived. It has the form of two Holland rose cuttings joined base to base, and is particularly appropriate for stones which are to be used as pendants or pendant eardrops. Set in a loop which clasps the girdle, it would seem that the brilliancy of this

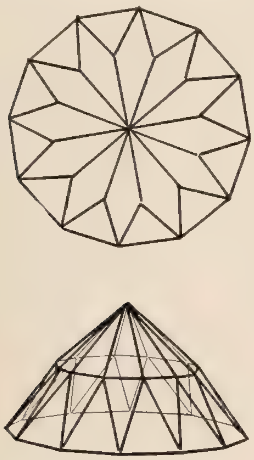


Figure 20

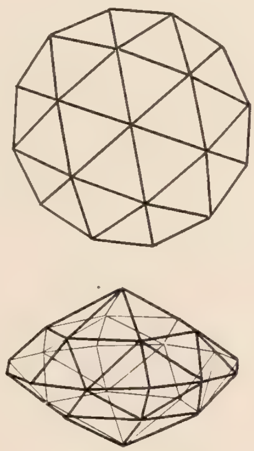


Figure 21

cutting, as applied to diamonds, has been somewhat overlooked; a study of the optics brings out the fact that it gives very effective reflections through the cross facets and that these reflected rays would, in all probability produce through their interference a desirable play of color.

So closely allied to the double rose as to almost constitute part of the same variation are the numerous forms of pendeloque cutting.[1] These may be considered as double rose cuts of which the axis of one end has been drawn out to a very steep crown, while the other end is terminated by a rose of ordinary height of crown or by one with this height slightly depressed. The pendeloque shown in Fig. 22 may be said to be formed by

[1]There appears to be a diversity of nomenclature in relation to this form of cutting, several authors mentioning it as a "briolette" or "briolette brilliant." In using the term "pendeloque" the present author follows the precedent of Dr. Max Bauer.

two cross roses and represents a rather simple cutting in this style. For pendants of the semiprecious stones pendeloque cuttings are eminently adapted and they are met with most frequently in the make of the quartz gems, rock crystal, amethyst, citrine and smoky quartz. The larger stones are given a more elaborate treatment, as in Fig. 23, which was studied from a smoky quartz pendant. Still more elaborate variations are common in the treatment of this cutting, some of them running as high as 88 or more facets. Much latitude is also permissible with regard to the proportion of length to diameter, and the shorter forms when

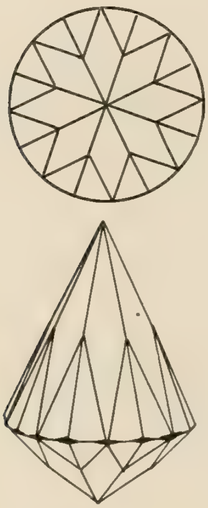


Figure 22

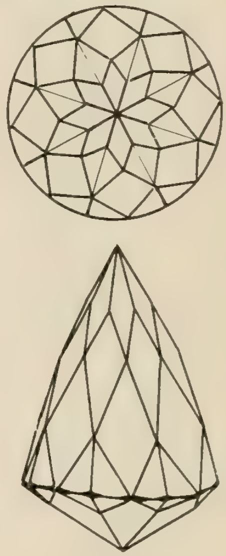


Figure 23

cut from relatively soft stones are usually bored through the axis to admit of their being strung.

From the pendeloque cutting it is but a short step to the beads and other cuttings intended to be strung. One of the most usual forms of round bead cut is the one shown in Fig. 24 which was studied from an amethyst bead of $13\frac{1}{4}$ carats. This treatment of a facetted bead may be found in almost all the materials used for this purpose, particularly in amethyst and amber. That it is a very ancient and obvious method of facetting is evidenced by the beads of the Gallo-Roman Period shown in Case XXIX of the Gem Series.

A much more unusual bead cutting is that shown in Fig. 25 and which might be termed a stepped bead. It was studied from one of a string of 29 superbly cut rock crystals and represents one from about the

middle of the string which weighed about 15 carats. Some of the larger of these beads were cut with cross facets for the two terminating rows of facets, and, in at least one instance, one end of the axis was treated as in the figure, and the other facetted for two rows as in Fig. 24.

Allied to these bead cuttings is the egg-shaped cutting given to the large blue topaz, illustrated in the frontispiece and to be found in Case VI of the Gem Series. This stone, which represents one of the finest examples of the lapidary's art, is cut with 444 facets of perfect regularity, and is so proportioned that it gives very effective brilliancy.

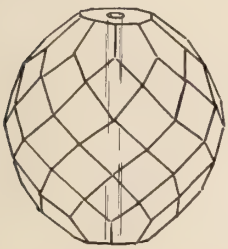


Figure 24

Figure 25

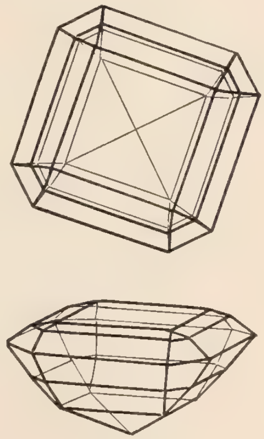


Figure 26

THE STEP CUT

When we turn back to the beginning of the art of shaping gem minerals into forms adapted to jewelry settings, we find a perfectly obvious sequence in the development of these forms. It is a sequence which, in fact, adheres closely to the lines upon which a lapidary of the present day is trained in his art. First, we have the round or oval cabochon cuttings of Celtic, Byzantine and early French jewelry, often somewhat irregular in shape, the simplest and crudest efforts in the dawning art of fashioning stones to enrich the masterpieces of the Medieval gold and silversmiths. With the development of richer design in jewelry there followed a steady progress in gem cutting, and with the call for stones of square and octagonal outline there began to be evolved cuttings with broad table facets flanked by narrow bevels to admit of the stones being gripped by the heavy settings. This early form of facetted cutting, which is essentially a primitive step cut, shows its influence in the presence of a table facet on early forms in the evolution of the brilliant cut. (See Figs. 3 and 4).

From such crude beginnings to the typical emerald cut Fig. 26 of the present day, the advance has been only along the lines of more complex and symmetrical facetting, produced with a view to making a stone of more elegance of outline, where the display of the color is the primary consideration. In this way the form of step cut shown in Fig. 26, is very widely used for emeralds and is given proportions directly dependent on the depth of color in the stone to be cut.

A fairly recent practice in diamond cutting has adapted the step cut to the making of diamond gems of especially choice quality. When applied to diamond, however, the proportions of the step cut must be carefully studied with respect to the effective rays of light which are returned through the crown facets after total reflection within the stone.

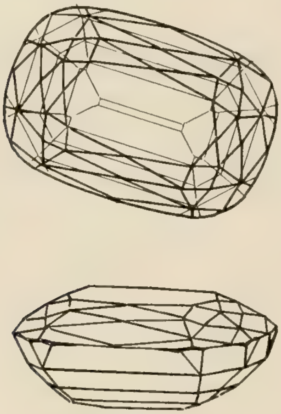


Figure 27

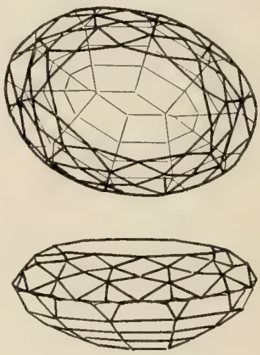


Figure 28

By far the most widely recognized derivatives from the step cut are those combination cuttings which use a brilliant or modified brilliant cut treatment for the crown facets and a stepped facetting for the pavilion end of the stone. One of these derivatives has been already discussed under variations of the brilliant cut, for the reason that it belonged more properly among the cuttings with round girdles than in the present group of cuttings, which include oval and oblong variants of the step cut, notably characterized by their complex multiplication of facets.

Cuttings of this kind are almost universally applied to large stones of the light colored gem minerals, such as amethyst, aquamarine, topaz, citrine, light colored tourmaline, peridot, smoky quartz, etc. In the example illustrated in Fig. 27, which was studied from a blueish green aquamarine of 30½ carats weight, the brilliant cut treatment of the

crown includes two rows of main facets instead of one, the large size of the stone necessitating an increase in the number of facets to give symmetry and surface brilliancy to the cutting.

Fig. 28 was also studied from an aquamarine, in this instance a stone of 13½ carats. The oval shape is produced by the use of 10 instead of eight groups of facets, and, as in the former instance, the main facets are doubled in the crown and the stepped facets of the pavilion are accommodated to the oval girdle by single corner facets. The beauty of this stone has well repaid the lapidary for the labor of cutting 122 facets which constitute its make and it may well be considered a masterpiece of well balanced and accurate gem cutting.

With larger stones the number of facets demanded by this cut may be increased almost indefinately. Leopold Claremont illustrates[1] a very large oval aquamarine which is cut with 313 facets in the crown alone. But unless well proportioned and symmetrically distributed the multiplication of facets in the combination step-brilliant cut tends only to detract the eye from the color, which constitutes the real beauty of the large semi-precious stones.

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[1] "The Gem Cutter Craft," page 182.

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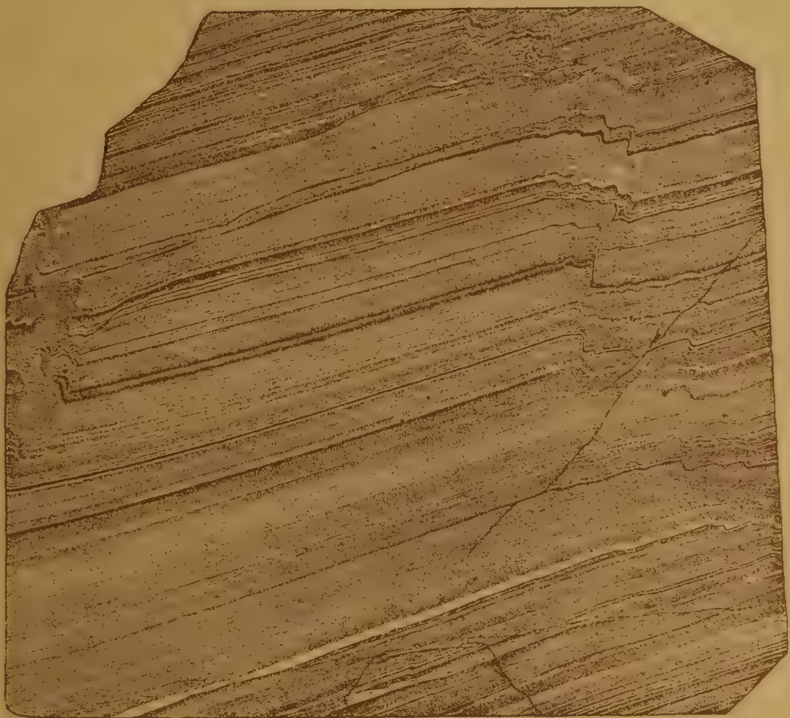

By CHESTER A. REEDS

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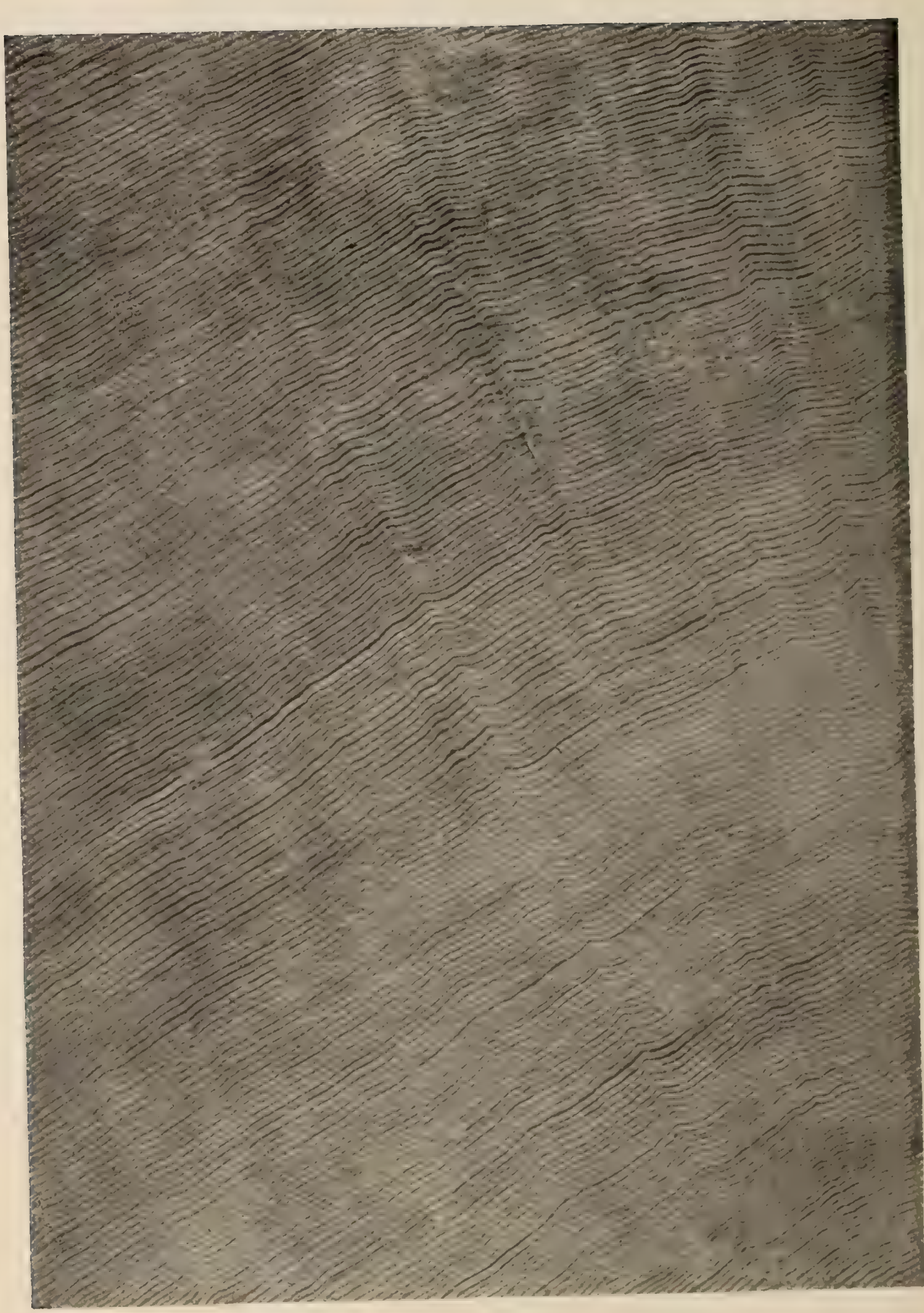
Seasonal Records of Geologic Time

BY

CHESTER A. REEDS

[*Reprinted from* NATURAL HISTORY, VOL. XXIII, NO. 4, 1923, pp. 370-380]



TREE RINGS USED IN MEASURING TIME

Two hundred three years of seasonal records, as shown by the annual rings (natural size) on the section of the big *Sequoia* tree in the American Museum of Natural History. Time represented 1150 A.D. to 1353 A.D.

Seasonal Records of Geologic Time

AS NOTED IN ANNUAL RINGS OF TREES, BANDED GLACIAL CLAYS, AND CERTAIN DEPOSITS MADE DURING PERIODS OF ARID CLIMATE

By CHESTER A. REEDS
Associate Curator of Invertebrate Palæontology, American Museum

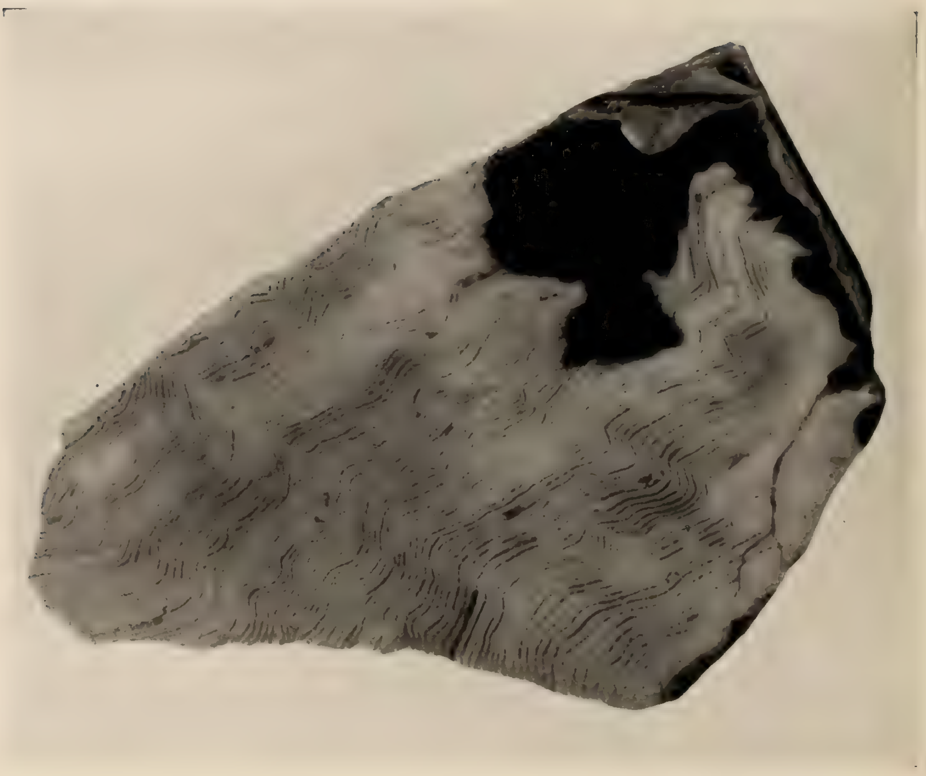
WE are all impressed with the variable daily amount of light and heat received from the sun and with the recurrence of day and night caused by the revolution of the earth on its axis every twenty-four hours. We are not unmindful, too, of the gradual passing of the seasons, spring, summer, autumn, and winter, and the accompanying variations in temperature and moisture, as the earth completes its annual circuit about the sun. The questions naturally arise: what is the net result of these seasonal fluctuations, for how many years have they been going on, and what will be their tendency tomorrow? We turn to the past records for an indication as to the future. We know that there have been seasonal variations for the thousands of years that man has been keeping his calendars and writing history. We also have good reason to assume that they were true for prehistoric man, who kept no tangible records, as well as for the great eons of time that preceded the advent of man upon the earth.

Those of us who have observed nature in one or more of her varied phases are greatly impressed with the effect of the seasonal changes upon the plants, which have adapted their growing periods to spring and summer, and their resting or maturing stages to autumn and winter. The researches of Dr. Ellsworth Huntington and Prof. A. E. Douglass on trees and climate are especially interesting in this connection.

In the trees the seasonal changes are recorded in the annual rings. Soft white cells grow at a rapid rate in the spring. This growth is dependent upon the relative amounts of snowfall and rainfall of the preceding winter as well as upon the porous or compact nature and depth of the soil. In the autumn, due to lowered temperature or diminished water supply, there is a gradual cessation of the activity of the tree. This change is recorded by the deposition of denser and darker material in the cell walls. During the winter, growth practically stops.

Occasionally, due to two stages of growth in one year, superfluous rings may arise, or, due to the lack of a spring development, two or more autumn rings may merge together and an apparent omission of rings will occur. To detect a possible error in counting these abnormal rings, groups of rings in different trees are compared and "cross-identifications" are thus established. Years deficient in rainfall or lowered temperature are more noticeable and more widespread than favorable years, for a deficient year is characterized by an individual ring that is small compared to those beside it. Large rings are more apt to come in groups and are not so extensive geographically as small rings.

Variations in climate can thus be detected in the growth rings of trees. Successive years are not all alike, for a factor like rainfall may be variable; besides, more than one factor may



A portion of a fossil Sequoia tree of Middle Tertiary (Miocene) age from the Yellowstone National Park, showing annual rings

affect the tree rings, such as rainfall, temperature, and length of growing season. In regions where trees have an abundance of moisture there is often noticed a beautiful rhythm of annual rings which matches with the sun-spot cycle of 11.4 years. Other cycles of 6 years, 22 years, 35 years, and 100 years have been noted. In fact, different centuries may have different combinations of climatic cycles. When they are better known, they may give us a basis for long-range weather forecasting. Some of them have been used by Professor Douglass in determining the relative dates of prehistoric ruins in northern New Mexico.[1]

[1]See the article entitled "Dating Our Prehistoric Ruins," by A. E. Douglass, NATURAL HISTORY, January-February, 1921, pp. 27-30.

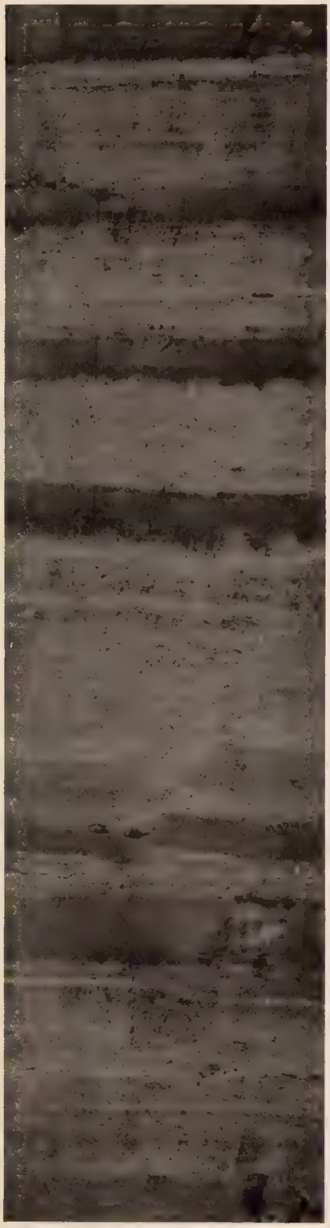
The longest record of tree growth is that found in the "big trees" of California, the *Sequoia washingtoniana.* Some of these trees have lived for more than 3000 years. In the Jesup collection of North American woods in the American Museum, there is a cross section of a large *Sequoia* tree which was cut in 1894. According to the count of the annual rings this tree started to grow in A.D. 550. Recently Doctor Huntington has added to this exhibit a climatic curve based on the variable growth in the *Sequoia* and has indicated the rise and decline in response to climatic variations of the great governments of the countries bordering the Mediterranean from 1300 B.C. to the present. This comparison is

possible since a study of the countries bordering the Mediterranean shows that the climatic pulsations felt there were similar to those indicated by the "big trees" of California, and indeed the climate of the two regions is still of the same type.

From the trunks of fossil trees it is probable that a very much longer record will be obtained. Trunks of fossil *Sequoia* trees occur in the Yellowstone National Park, in the eastern foothills of the Rocky Mountains, and elsewhere, in places where the trees do not now grow. The cross section of the silicified wood sample, p. 372, shows ninety-two well marked rings with a thickness of about one millimeter each. Fossil woods exhibiting annual rings have been found in rocks of various ages from the Upper Devonian Period to the present, that is, as far back as 18,000,000 years ago, but only comparatively few have been collected and are accessible.

A longer annual record than that afforded by the living *Sequoia* trees has been obtained in Sweden from the glacial clays deposited in fresh-water lakes which laved the retreating ice front of the last continental glacier. The stratified clays of the Hudson, Hackensack, and Connecticut river valleys and of many other points in America were likewise deposited in fresh-water lakes which followed the retreating ice border of the last great North American ice field.

On close inspection these glacial clay deposits show distinct seasonal layers or bands: a summer layer, which is the thicker, of more sandy material, and of lighter color, usually gray; a winter layer, which is the thinner, of very fine clay, and of darker or reddish color, depending upon the color of the rock from which the fine clay particles were derived. In passing upward from a dark winter layer to the



Banded glacial clay (varve clay) from New Haven, Connecticut, showing seven dark winter layers and six lighter summer layers (natural size). An annual deposit consisting of a summer layer and the succeeding winter layer is called a varve. Collected by Dr. E. Antevs, 1922

Postglacial banded clay exposure at Dunnings Point on the Hudson River near Beacon, New York. Photograph by the author, September, 1922

Varve clay from clay pit one-quarter mile north of Mountain View, New Jersey. The deposit was made on the bottom of the former glacial lake, Passaic. Photograph by the author, September, 1922

coarse gray summer layer, the change is abrupt; from the summer layer to the winter layer, however, the change is gradual in all cases. The coarse summer layers have very fine wavy lines of bedding while the fine winter layers are homogenous and uniform in appearance. These seasonal layers alternate in position without exception throughout the deposits. A pair of such layers is called a varve, or annual deposit.

In different years different quantities of sediments were carried to the glacial lakes and consequently there arose variations in the thickness of the varves. Over the several areas of sedimentation, however, the varve for a particular year is approximately of the same relative thickness. Another circumstance of considerable note is that the varves overlap each other very much like the shingles on a roof. This was brought about by the amount of summer melting and the annual retreat of the ice northward. The location of the northern limit of each varve, that is where it touches the bed rock, thus enables one to determine the position of the ice for a particular year as well as the rate of retreat.

In Sweden the rate of glacial retreat was irregular; in Scania and Belecking about 75 meters a year. Before reaching the two great Fennoscandian moraines near Stockholm, which represent distinctly adverse climatic conditions, it increased to 100 meters or a little more. North of the great moraines the retreat fluctuated from 100 to 300 meters or more a year and only occasionally was it interrupted by a stoppage or small advance.

This retreat of the last glaciation in Sweden, (see map) may be subdivided and summarized as follows:

(1) Daniglacial—Part of Denmark, part of Scania, and north central Germany south of the Baltic Moraine. Time undetermined.

(2) Gotiglacial—Retreat from the terminal moraines in middle Scania to the southern border of the great Fennoscandian moraines south of Stockholm, 11,600 B.C. to 8600 B.C., or 3000 years.

Retreat stages of the last glaciation in northwestern Europe. After Osborn and Reeds, 1922

(3) Finiglacial—The retreat from the southernmost of the Fennoscandian moraines to the parting of the land ice into two parts in the Ragunda district, 8600 B.C. to 6600 B.C., or 2000 years.

(4) Postglacial of Swedish geologists, based on the work of Lidén in the valley of the river Angermanälven, 6600 B.C. to 1900 A.D., or 8500 years. The above figures give a total of 13,500 years for the retreat of the last ice sheet from central Scania to the present small ice caps in north central Sweden.

The glacial clay studies in Sweden have been made chiefly by Baron Gerard de Geer[1] and a number of younger men trained by him, particularly Dr. R. Lidén and Dr. E. Antevs. It was in 1878 that De Geer arrived at the conclusion that a pair of these seasonal layers constituted an annual deposit, or varve. De Geer also developed a method of correlating these

[1]See the article entitled "Baron Gerard de Geer and His Work" by James F. Kemp. Natural History, Vol. XXI, pp. 31-3.

deposits not only in the same region but also in different regions.

Studies of glacial clay, deposited during the retreat of the last ice sheet in North America, have been made by a few investigators, particularly Antevs, 1921–22, who has determined a sequence of varve clays representing 4100 years for the retreat of the ice front from Hartford, Connecticut, to Saint Johnsbury, Vermont, a distance of 185 miles. The average rate of retreat was a little more than one mile in 22 years, but it was not regular. Between Springfield and Amherst, Massachusetts, a distance of twenty miles, it was much slower, about a mile in 47.5 years. Then for 350 years the ice front remained in the vicinity of Amherst, but at the termination of that span of years retreated more rapidly, about a mile in 15 to 16 years. The results of Doctor Antevs' investigations have been published in book form, under the title of *The Recession of the Last Ice Sheet in New England*, by the American Geographical Society, New York, 1922.

Banded clays of an earlier glaciation were described by Prof. R. W. Sayles in 1916 from the Sqantum peninsula near Boston, Massachusetts. It is estimated that they are 13,000,000 years older than the clays deposited during the retreat of the last or Quaternary (Pleistocene) glaciation of northwestern Europe and eastern North America. They are 800 feet thick and have been referred to the Permian Age, a period nearly one-fourth the way down the geological scale (see p. 378). Since deposition these ancient banded clays have been converted by diastrophic movements into slate or argillite, but they still retain their original relations and characteristics.

The most ancient glacial clays with varves so far noted appear near the base of the geological column and are estimated to be 37,000,000 years old or older. They exist as argillites associated with the Huronian glacial drift deposits at Cobalt, Ontario, Canada. According to the late Prof. Joseph Barrell, they occur at the south end of Cobalt Lake; they are delicately banded and indicate rhythmic deposition. The bands are grouped in series that show larger rhythms representing climatic fluctuations covering periods of years.

Deposits made under arid climates sometimes show seasonal developments. According to R. Görgey (1911) seasonal bands appear in certain salt deposits of northern Germany. Varves representing 5653 years have been noted in these deposits. The salt beds which exhibit this banding are associated with red formations and gypsum of Upper Permian age. Unlike the varve clays, which formed under a moist glacial climate, these salt deposits were developed from brines under a period of continued arid climate characterized by excessive evaporation during the summer.

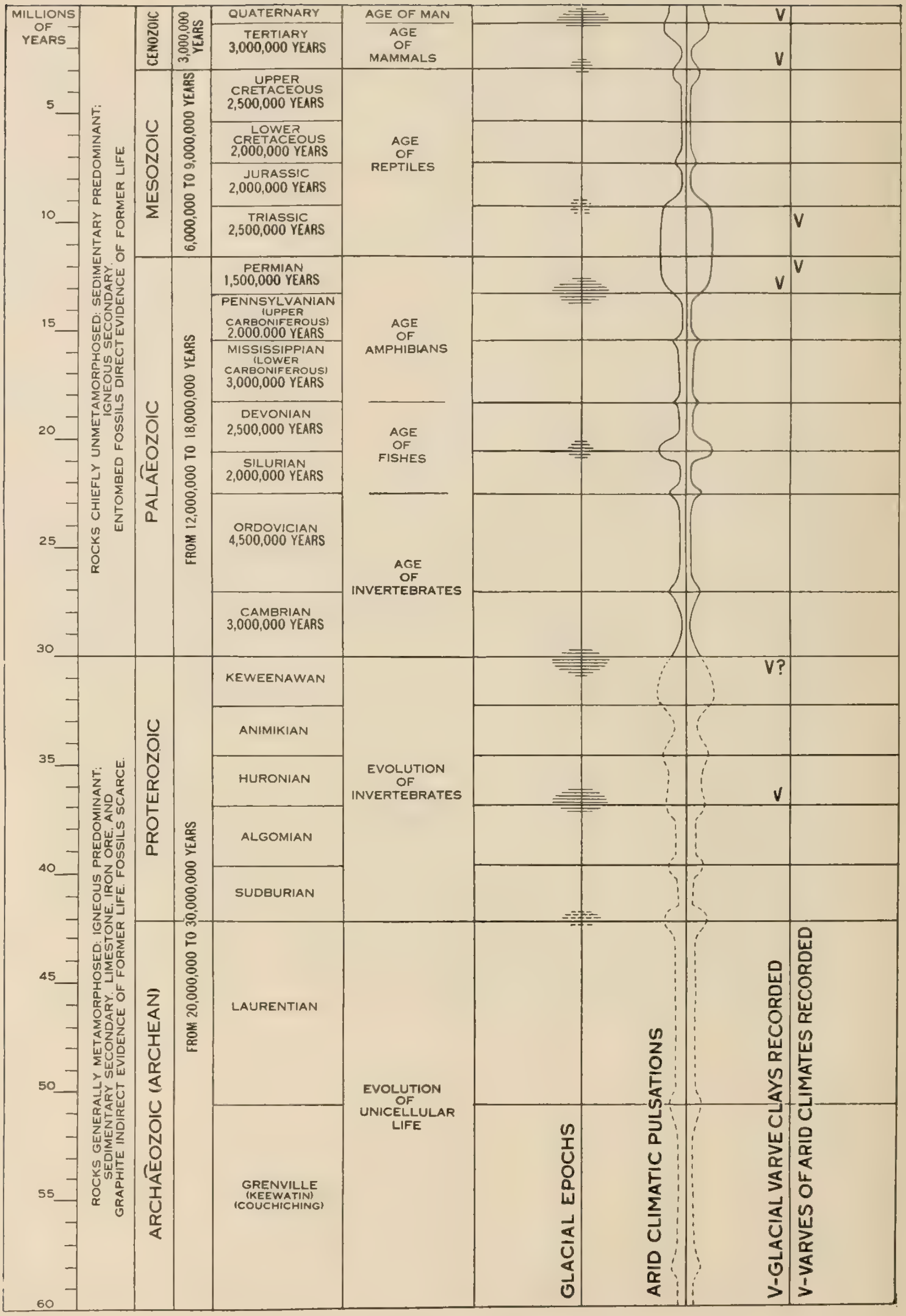
Another example of seasonal bands formed under an arid climate is furnished by the specimen of Triassic red sandstone shown on p. 377, which the author found in September, 1922, as a sporadic bowlder in the five feet of "yellow drift" overlying the late glacial clays of the Quaternary (Pleistocene) Period in the vicinity of Little Ferry, New Jersey. The normal position of the Triassic rocks in this region is beneath and on the margins of the Pleistocene clays. In cross section this specimen shows more than nineteen annual bands of red sand. The summer layers are the lighter in color and are

relatively thick with moderately coarse sand; the winter layers are the darker and are thin, being composed of a finer grained sand than the summer bands. The varves are quite regular and show marked seasonal differences.

From the instances cited it is apparent that seasonal records of one kind or another occur at widely separated intervals in geologic time, in fact so early and so late and with sufficient frequency to justify one in assuming that seasonal changes took place regularly from year to year throughout all geologic history. Seasonal records, however, have not been preserved for every year, as a certain combination of circumstances must exist to bring about deposition. Sharply marked seasonal deposits were formed either under glacial or under arid conditions, that is, the two extremes of climate. Furthermore, their presence is restricted to the fresh-water lakes which laved the retreating ice front or to the vanishing lakes of arid regions. The marine formations, which constitute the greater portion of the stratified rocks of the earth's crust, show no varves or seasonal banding; hence deposits exhibiting varves form only a small part of the geologic record. Such deposits are of the greatest importance, however, in the study of geochronology, climates past and present, and the evolution of life.

Cross section of varves in a Triassic red sandstone bowlder from Little Ferry, New Jersey

Where varves exist, they can be counted and the actual length of time involved in their deposition ascertained. In the many instances, however, where they do not exist, the duration of time is uncertain; nevertheless, the thou-



A CHART OF GEOLOGIC TIME

The glacial epochs are shown by the shaded areas (dotted where the data are indirect); the arid climatic pulsations by a curved line (dotted where the data are indefinite); and the varve deposits by a V, placed on the left of the ruled line where glacial action is responsible and on the right of the line where the varves were produced by arid climates

sands of sedimentary beds represent millions of years for their deposition. Competent observers using different criteria have made various estimates as to the age of the earth. Some say that it may be 60, 100, 200, or even 750 million years old. Whatever the true estimate may be, there are actual beds of rock which represent a tremendous length of time for their deposition.

In recent years many geologists have concluded that the earth's climate has pulsated back and forth and that a stable climate has not prevailed for any great length of geologic time. There have been periods when extensive land areas, now comparatively free of ice, were covered with great ice sheets. At other times arid to semi-arid or desert conditions oftentimes prevailed in the same or even higher latitudes. To account for changes in civilization at various places in historic times, Prof. A. Penck and Dr. E. Huntington point to the shifting of climatic zones back and forth and cite examples along the northern and southern margins of the Sahara and Sonoran deserts.

Now it may be observed that due to repeated oscillations of the climate during geologic time from one extreme to the other, life has passed through successive crises and that each crisis was a step forward toward the estate of man. The various groups of life which have been successively dominant on the earth have been listed in the life column on p. 000. That these various classes of life are genetically connected is known (1) from the recapitulation, in the embryological stages of the higher animals, of the types of life that have preceded them; (2) from the finding in the geological record of large numbers of fossil specimens which bear witness of this connection and development.

Variations in climate should not be regarded as the sole cause of evolution but one of four or more contributing factors which Prof. Henry Fairfield Osborn has considered in his book, *The Origin and Evolution of Life.* It may be noted, however, that geologic and secular changes of environment have preceded many of the most profound changes in life.

In the Archæozoic Era, which embraces the oldest rocks, there is indirect evidence that unicellular forms of life were present, also that nothing higher existed.

The Lower Huronian Period, with an extensive glaciation in southern Canada and other parts of the world, was among the first of the critical life periods. The Archæocyathinæ, coral-like animals, appear in great numbers before the close of the period. They represent the oldest invertebrates known and an early step forward in the evolution of life from the unicellular forms.

Toward the close of the Proterozoic Era another pronounced glacial climate prevailed in various parts of the world, the net result of which was the sudden appearance in the Cambrian rocks of numerous examples of all classes of marine invertebrates. It is also probable that the tendency toward vertebrate life was initiated at this time, for primitive fossil fishes have been found in the Upper Ordovician rocks of Colorado and Wyoming.

The next important crisis occurred in the late Devonian when, due to the rather extensive arid conditions in many parts of the world, there was an emergence of the earliest vertebrates from the water. Huntington says it was drought which apparently drove our

fishlike ancestors out of the water upon the land. He considers this a most momentous step, for only in the highly varied environment of the land does brain power develop rapidly.

Glacial conditions which were to have a far-reaching effect upon life returned in the late Pennsylvanian and again in the Permian periods. The Permian glaciation was prominent in both the southern and northern hemispheres to within 30° of the equator. It was during these trying times that the warm-blooded mammals probably arose. Their bones, however, have not been found earlier than the Upper Triassic. According to Huntington, the transition from cold-blooded to warm-blooded animals represents one of the most profound developments in the history of evolution.

Throughout the Mesozoic Era the reptiles were the grand masters of the realms of land, air, and sea. During this time they waxed strong, deployed widely, and became adjusted to their environment. Then there came a great change over the landscape in the early Tertiary: the Rocky Mountains were uplifted, seas and marshy lowlands were drained, glaciation returned, the reptile horde was diminished, and the mammals became the dominant class.

The mammals in turn took on many diverse forms and, like the reptiles, occupied all the media of land, water, and air during the millions of years of the Tertiary Period. When they had reached a condition of complete dominance and adaptation, they too were suddenly wiped out in wholesale lots. This may be attributed directly or indirectly to the severe climatic vicissitudes of the Pleistocene or early Quaternary glaciations.

The Quaternary Period is called the Age of Man. In Europe south of the fifty-third parallel evidences of Pleistocene man and even of a late Tertiary (Pliocene) man have been found. Successive types of men lived, struggled, and endured the privations of the glacial and interglacial epochs. During these times the cultural development of man centered about the perfection of stone implements of chipped flint, the palæolithic stage; then during the short Postglacial stage, with its minor climatic oscillations, he passed rapidly through the neolithic into the historic and modern culture stages. According to Huntington, it was apparently this Glacial Period which chiefly stimulated man's mental development and caused his intelligence to dominate the earth.

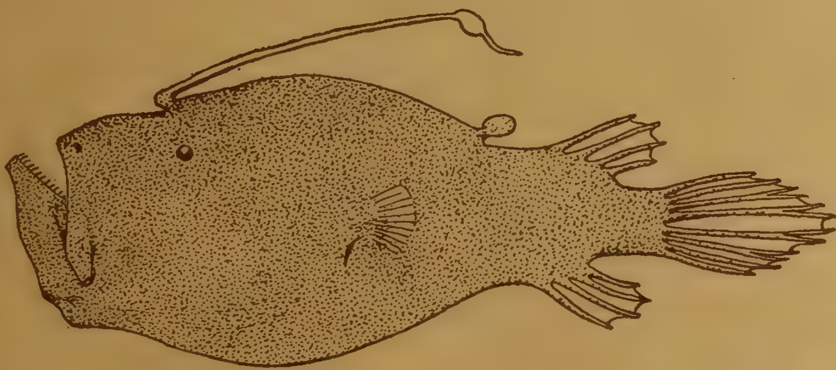
We pause on the threshold of the future; we dare not enter, for we have a profound respect for the past. We know that this is the Age of Man but we do not know what the next age will be. We feel assured that seasonal and climatic variations will continue in a pulsatory way as before, but as to man he will in all probability succumb in time, as did his ancestors, to the natural forces that caused him to rise and conquer.

THE AMERICAN MUSEUM OF NATURAL HISTORY

DEEP SEA FISHES

BY

LOUIS HUSSAKOF



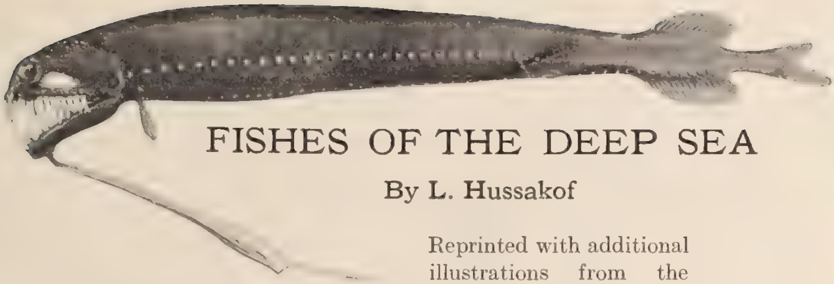
New York, 1925 Third Edition

Reprinted from the AMERICAN MUSEUM JOURNAL

SOME DEEP-SEA FISHES

Some characteristic types of fishes found in the profound depths of the sea, half a mile or more from the surface, photographed from a group installed in the hall of fishes in the American Museum. The illumination of the group is so adjusted that the fishes are seen first for a few seconds in full light, and then in darkness as they are supposed to appear in the sea, lit up only by their own phosphorescent organs

The specimens are models, mostly enlarged several times the natural size. The fishes were prepared by Mr. F. F. Horter of the Museum's department of taxidermy, under the direction of Dr. L. Hussakof



FISHES OF THE DEEP SEA

By L. Hussakof

Reprinted with additional illustrations from the American Museum Journal for 1915, Vol. XV, pages 248–253.

UP to the time of the "Challenger" expedition, very little was known regarding the fish life of the abyssal depths of the sea. Only about thirty species were known. But the wonderful collections brought back by the "Challenger" from her four-year cruise (1873–1876) made known the vast diversity, the strangeness and even weirdness of this fish fauna. Several hundred kinds of deep-sea fishes had been collected—some of them dredged from a depth of more than a mile—and it required a huge quarto[1] to describe and picture them. From this volume dates our real knowledge of the fishes of the abyssal deep. The "Challenger" expedition was, indeed, a "Columbus voyage" in ichthyology; it opened a new chapter in the history of the science.

Since that time many deep-sea exploring expeditions have been sent out by the various nations, and hosts of other fishes have been brought up from the oceans in all parts of the world. More than a thousand species are now known, and we can appreciate at its full value the richness and strangeness of this fauna. A large proportion of these fishes are described and figured in two quarto volumes by G. Brown Goode and Tarleton H. Bean, entitled *Oceanic Ichthyology*, published by the U. S. National Museum. Moreover, not only do we know the fishes themselves, but as a result of the scientific investigations carried on by the various expeditions, we now know a good deal of the physical conditions under which they live, so that we can, in a measure at least, explain the why and wherefore of their extraordinary characteristics.

When we think of life in the deep sea, there comes to mind, first of all, the enormous pressure which these creatures must withstand. This pressure becomes the greater the deeper we go down, and in the profoundest depths it equals thousands of pounds to the square inch. The result of this pressure is that the tissues of these fishes are tender and loosely knitted together. When they are brought up out of the dark depths, and the great pressure under which they live is removed, the explosion of the gases within them bulges out the eyes, and often blows out the viscera through the mouth, while the muscles collapse, leaving them soft and flabby like moist rags. Most deep-sea fishes are very small also, usually only a few inches in length, and it is probable that this reduction in size has come about to some extent at least, from the great pressure under which they live.

Another important condition is the dimness of light, or even darkness in the profound depths of the sea. If we imagine ourselves descending into the deep ocean, we see the light grow dimmer and dimmer as we go down, until

[1] *Challenger Reports*, Vol. XXII, 1887.

finally a level is reached beyond which no light penetrates at all. The entire avst depth below it is in eternal darkness. Now the fishes living in this dim light, or in total darkness, have been profoundly modified by it. In some forms the eyes have become very small, and in some cases have entirely disappeared. There are even fishes in which the skin and scales of the body have grown over the place where the eyes should be, so that these fishes are, as has been aptly said, "blind beyond redemption." Other forms, on the other hand, have been affected in an entirely different way. The eyes, instead of growing smaller, have grown larger, as if in an attempt to catch every fleeting ray of light. In some fishes this has been carried so far that the eyes have become like enormous goggles.

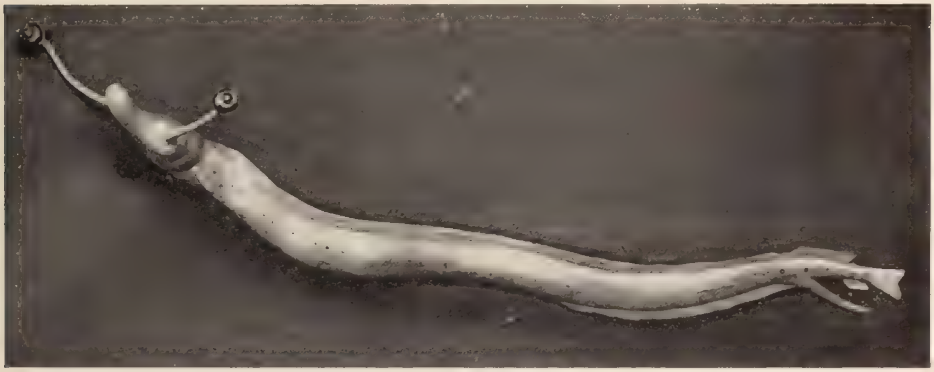
In this deep-sea fish the head glows with a soft pale light, while the body is quite dark, being covered with large opaque scales. The species (*?Opisthoproctus soleatus*) is known by only two examples dredged from a depth of two and a half miles; one off the northern, and the other off the western coast of Africa

This specimen is not shown in the general photograph of the group, having been cut out for convenience in reproduction. It is situated in the group below the bottom fish on the right-hand side

Most deep-sea fishes have luminous organs of one kind or another, so that they carry their own light about with them. In some the entire body glimmers, the coating of slime which exudes from the pores and lateral canals emitting a soft silvery glow. In others, rows of minute, luminous organs run along the sides of the body, or there are flashing light-spots on the head or face. What a wonderful sight would be to us a small black fish flitting through the silence and darkness of the deep with its headlights and row of pores gleaming through the darkness like some small ship passing through the night with its portholes all aglow! Some deep-sea fishes have a luminous organ at the end of a feeler on the head. This is waved to and fro to act as a lure to attract the prey.

A pertinent question may be asked: How do we know these fishes glow and glimmer, since no human eye has ever beheld them in their abyssal home? We know this partly from analogy and partly from actual observation. When one is in a boat in the tropics, on one of those sultry nights when everything is a dead calm, and the black clouds hang

so low that sky and sea form one continuous blackness, then one may see the glimmering fishes darting out of the path of the boat, their forms, silvery and ghostlike, outlined for one moment against the blackness of the sea. This effect is chiefly due to the oxidizing of the slimy secretion covering their bodies. Why shall we not believe, then, that in deep-sea fishes a similar phenomenon takes place, particularly as in many of them, the slime pores and canals are greatly developed and must exude large quantities of slime? Then too, on deep-sea expeditions, on favorable occasions, as for instance, a dark calm night, fishes that have been brought to the surface and placed in water were seen to flash light from the ends of the tentacles or the phosphorescent pores, precisely as we should have expected from a study of these organs. Major Alcock, in his interesting volume *A Naturalist in Indian Seas*, mentions a specimen brought up from a profound depth which "glimmered like a ghost as it lay dead at the bottom of the pail of turbid sea-water." So that by inference, as well as by actual observation, we must believe that what we call luminous organs in deep-sea fishes, emit light into the darkness about them. In the case of fishes totally blind, the absence of light is compensated for by the development of enormous antennæ-like feelers, modified from fin rays, so that these fishes can feel their way, as it were, through the darkness.



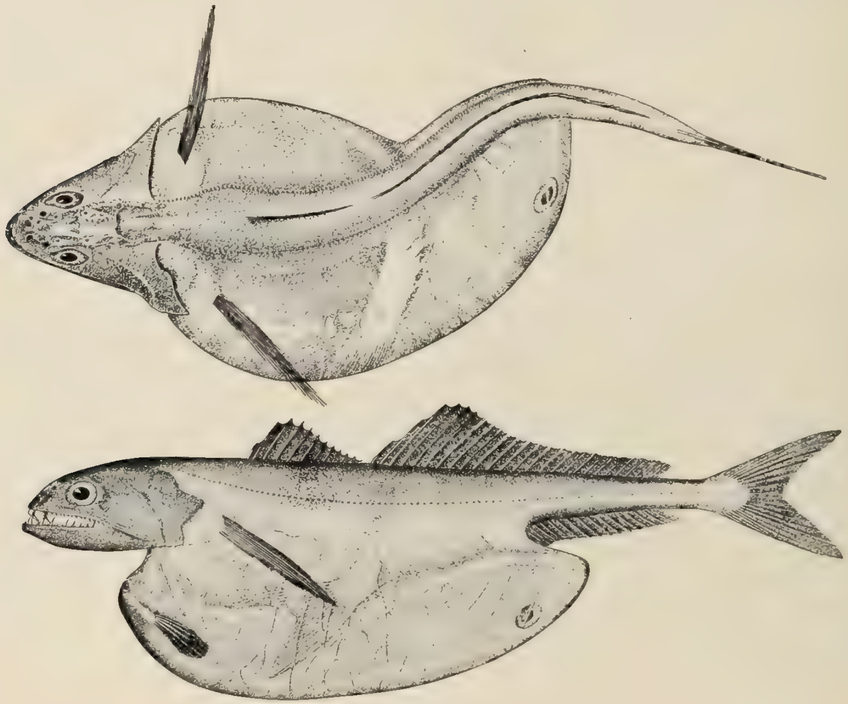
A small, silvery, eel-like fish which has been found in all the oceans at depths ranging from a little less than a mile to two and one-half miles. It has a row of luminous pores running the length of the body; and, in the blackness of the profound depths it must appear like a miniature long dark boat with gleaming portholes. Its greenish, glittering eyes are perched on the ends of slender, hornlike tentacles—a feature which has suggested its scientific name, *Stylophthalmus paradoxus*

The absence of light however entails another important consequence. As is well known, no plant life can exist in darkness. There is, therefore, no vegetation of any kind in the profound depths of the sea. The deep-sea fishes are, in consequence, all carnivorous, the more powerful ones seizing and devouring the weaker ones. It is a cold black world where might reigns supreme. Many have enormous mouths, and formidable teeth to insure holding the prey. In some forms the teeth are so large that the mouth cannot be shut! Moreover, since meals are perforce far between, they must be as large as possible; hence many forms have extraordinarily capacious stomachs. Speci-

mens have been dredged from the deep which were enormously distended through having swallowed fishes larger than themselves.

The temperature of the water in the profound depths of the sea is always low and near the freezing point. This is true everywhere, even at the equator. Undoubtedly this has an effect upon the fishes, although it is not yet known what it is. The amount of oxygen dissolved in the water also, is much less than in water nearer the surface. The breathing apparatus of the deep-sea fishes is modified to suit these peculiar conditions. The gill filaments have become much reduced in size, and in a number of instances some of the gill-arches bear no gill filaments at all. The fishes are apparently adapted to a much smaller oxygen supply than those living in rivers or in the shallow sea.

When we think of the vast diversity among these fishes, the question arises: Are they all representatives of a single family, or group, that has become specially adapted to life in the deep sea; or do they belong to different families or groups? One need hardly be an ichthyologist to answer this question. Even a cursory examination of the plates in a work on deep-sea fishes will show that different types are represented. In fact, a great many families are included in the deep-sea fauna. There are sharks and rays; salmonoids, herrings, perches, eels, and representatives of many other families. We can explain this heterogeneity among them in this way: we may imagine that fishes of many different kinds in their search, so to speak, for the unoccupied corners of the sea, found a haven in these deeper waters where they were



CHIASMODON

A fish that swallows fishes larger than itself; the original of this picture was nine inches long and had caught a fish eleven inches long

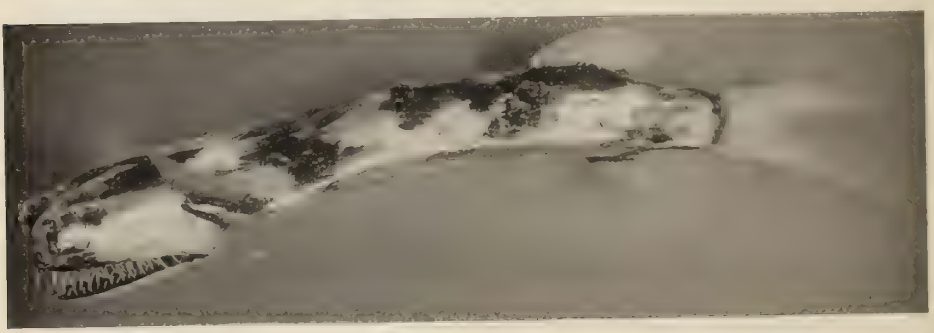
free from pursuit by their enemies. In the course of time they migrated farther and farther into the deep, a change in habits taking place *pari passu* with the changes in structure. Having started out with different degrees of variability, they became differentiated in diverse directions, so that while some developed enormous mouths, powerful teeth, or phosphorescent organs, others became bottom-living and partly or completely lost their eyes. Still others developed long feelers for groping their way through the darkness. Now and again, however, fishes of separate groups developed similar structures, so that there are many striking cases among deep-sea fishes of what the biologist calls "convergence," or parallelism.

CHIMAERA A DEEP SEA "SILVER SHARK"

A group comprising ten noteworthy examples of deep-sea fishes forms part of the exhibit of the Department of Fishes and may be found in the north corridor, second floor, by the Paddle-fish group. It was prepared by F. F. Horter and is the result of long and patient work and great ingenuity in overcoming difficulties. It is not, of course, a group in the sense of the habitat groups displayed in the Museum; it is not a section, so to speak, taken from nature and transplanted to the Museum. In nature so many deep-sea fishes are not to be found in so small a space. What the group represents is a number of fishes which are in nature scattered over a vast area and through a great height of water, here brought together for museum purposes into a few square feet of space. Each fish is reproduced accurately with its phosphorescent pores and tentacles as these are known to exist. With one or two exceptions they are enlarged several times, as the fishes themselves are very small. And since it is known that the phosphorescent organs do not glow with a steady light, the illumination of the group has been arranged so as to have these luminous organs flash intermittently. Furthermore, the installation is arranged so that one may view the fishes for a few seconds in full light, as if in a synoptic exhibit, and then see them, when the light goes out, as they are supposed to appear in the darkness of the profound depths, lit up only by their own phosphorescent organs.

Near the top of the group is seen a fish which lives on the border line between the region of dimness and total darkness. Many of the fishes living in this region are not of a uniform sombre hue, but are brilliantly colored. *Neoscopelus* is one of these. The body is "one dazzling sheen of purple and silver and burnished gold, amid which is a sparkling constellation of luminous organs" (Alcock).

The glowing fish in the center is *Barathronus diaphanus*, a small fish known from a single specimen, which was dredged in the Indian Ocean at a depth of a little over four-fifths of a mile. The model of it is one and one-half times the natural size. The phosphorescent fish with the curious long tail (at the right) is *Gigantura chuni*. It, also, is known by only a single specimen. This was brought up from a depth of four-fifths of a mile in the Gulf of Guinea, on the west coast of Africa. The model is twice the natural size.



This strange deep-sea fish (*Gigantura chuni*) is known by only a single specimen dredged from a depth of four-fifths of a mile, in the Gulf of Guinea on the west coast of Africa. The body of the fish is a shimmering glow of iridescence,.while the protruding eyes shine like automobile headlights. The formidable teeth mark it as a ferocious carnivore

The two dark fishes with enormous gaping mouths (near the top, at the right) are *Gastrostomus bairdi*. This species is commoner than some of the others, a number of specimens being in several museums. The models of it in the group are copied life-size from a specimen in the Museum. The species occurs in the Atlantic Ocean, near the American coast, in the path of ocean liners. Specimens have been dredged from a depth of nearly three miles.

Near the bottom of the group at the left-hand side, is seen an eel-like fish with a line of lit-up pores. This is an enlarged model of *Stylophthalmus paradoxus*, a small silvery fish widely distributed in all the oceans, whose young also are known. The generic name it bears was given it in allusion to the fact that the eyes are perched on long slender tentacles. The species ranges from a depth of a little less than a mile to two and one-half miles. Another form with tentacles is *Gigantactis vanhœffeni*, a species typical of many deep-sea fishes which have a tentacle, terminating in a luminous organ, attached to the head. This tentacle serves as a lure for attracting prey. The present species is known by only two specimens which were found in the Indian Ocean at a mile and a mile and a half from the surface. The creature is a very small fish, the model being enlarged six times.

Besides this group, enlarged representations of twenty other species are shown in a case at one end of the systematic series of fishes.

THE AMERICAN MUSEUM OF NATURAL HISTORY

BIRD-HUNTING IN CENTRAL PARK

BY LUDLOW GRISCOM

Assistant Curator, Department of Ornithology

GUIDE LEAFLET No. 68

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Photographed by Edmund O. Hovey

Swallows skim over its surface, the kingfisher watches in the overhanging trees, and the water-thrush trips along the bank

Black ducks on one of the smaller ponds. They are descended from wild birds

Bird-Hunting in Central Park

By LUDLOW GRISCOM
Assistant Curator, Department of Ornithology

FEW people without experience, would suppose that a park in the heart of a great city was an excellent station for the study of birds during the migration period. Bradford Torrey, years ago, used to tell the story of a friend who inquired of a distinguished ornithologist where he should go to obtain a sight of certain rare warblers. Much to his surprise, the advice was, "Go to Central Park, New York," though an undistinguished friend had already recommended precisely the same place! The writer has visited the Ramble in Central Park daily in spring and fall during the past eighteen years and can fully endorse the excellence of this advice. It is, indeed, an ideal place for a close study of migration. The reason is comparatively simple. The greater number of our local birds migrate at night. The electric lights of the city have a certain fascination for these little travelers, just as lighthouses are well known to have, and they fly lower, particularly on foggy nights. Secondly, the Park is a haven of refuge, a vetitable oasis in a vast desert of city roofs. As day breaks, the tired hosts must alight to rest and eat. How gloomy those individuals must feel who see nothing but the roofs of Newark or Hoboken beneath them by the dawn's early light,

and how inviting the lakes, lawns, and verdure of the Park must seem in the distance. Many indeed are forced by fatigue to alight almost anywhere. Washington Square has a notable list of birds, and a friend has recorded more than thirty species in a back yard on Tenth Street, which boasts one sickly little tree, surrounded on all sides by tall apartment houses. Anyone who stands on the bridge over the lake in Central Park at daybreak on a warm May morning will be able to appreciate for himself the force of this attraction. Calls of various species can be heard showering out of the blackness of the night in every quarter of the sky. As day breaks it is obvious that the birds are flying lower and lower, then they become dimly visible, less than a hundred feet overhead, and finally they can be seen pitching into the nearest trees. During the next half hour the chorus of song gradually swells as the travelers find food and rest, and the observer can set about recording the extent of the flight, and the new species which have arrived from the south. It also follows, parenthetically, that once having alighted, there is no special inducement to move on, as there is no suitable adjoining territory to go to. The smaller birds at least are caught until nightfall at the earliest, or until the instinct of migration inspires them to proceed another lap on the return journey to their breeding grounds. It frequently happens, therefore, that individuals of rare or uncommon species will remain for several days, or even a week, and give the student a real opportunity to cement a chance acquaintance.

It must not be supposed, however, that Central Park is an Eden for all the species of birds in the New York City region. The causes which attract night-flying birds do not apply, for instance, to those which migrate by day, and their one desire is to leave the dust and noise of the city behind them as rapidly as possible. As there are no marshes or feeding grounds for water birds, these are of purely casual occurrence. Similarly the absence of grassy fields and pastures deprives the park of any attraction for birds like meadow larks and vesper sparrows, which consequently are very rare. Few indeed are the birds which can endure the noise of the summer crowds, and the breeding species are steadily decreasing. Very few species now spend the winter unless a feeding station is started early enough in the fall and consistently maintained, as in late October the ground is carefully raked over and the shrubbery is trimmed to insure a good growth the next season. But these operations inevitably destroy part of the food supply and eliminate shelter and cover, so that the Park has no attractions as a winter resort. But the Park does offer a suitable habitat to the great majority of woodland and thicket-loving species which migrate by night, and they are as common, or even more common, than anywhere in the vicinity of the city.

Some figures might be of interest. Fifty years ago, when the park was on the outskirts of the city, nearly sixty species nested and many were common all winter. In 1908, eighteen species nested and twenty-two spent the winter. Last year, but eight species nested and a very few individuals of three native species spent the winter. This decrease was inevitable and was to have been expected, though bird lovers regret the disappearance of the cardinal and warbling vireo, and miss the friendly chickadees which used to snatch peanuts from between their lips in the winter time. The regular tran-

sient species have not been affected, however, and a daily visit from April 1 to May 30, and from August 10 to the end of October is certain to repay the student. The average list for such a series of visits is about 110 species per year. At the end of this article will be found a list of all the birds recorded from the Park, divided into two categories, (a) those of more or less regular or normal occurrence (116), and (b) those of very rare or casual occurrence (75). What usually happens is that some of the species belonging in list *a* are missed in any given year, and these are compensated for to a certain extent by two or three species belonging in list *b*. May is the star month, when the maximum number of species and individuals is present. There is always the possibility that a great "wave" of migrants will arrive overnight with favorable weather conditions. Such an occasion took place on May 10, 1922, when 66 species and thousands of inindividuals were observed in the Ramble. This is the record, but fifty species at least can usually be counted on, one or two days each season. Conditions are somewhat different in the fall, when the migration is protracted over a far longer period, and the birds move south in a more leisurely manner. The record list in fall is only 52 species on October 4, 1907, when a sudden cold snap, after a mild September, forced many laggards to rush south pell-mell. Indeed, it is exceptional to record more than 40 species in any one day. When we consider the absence of song and the change to a more obscure plumage, it is small wonder that the average bird lover is discouraged, and the swarm of observers in May is conspicuously absent in fall. Nevertheless, at least twenty-five of the rarer species are far more likely to be seen in fall than in spring, and a few are beyond the bounds of reasonable hope in May. During the past eighteen years, the writer has seen 160 out of the 191 species recorded since 1875.

How do these figures compare with the country outside the city limits? They are, of course, very much lower. If Sunday and holiday trips are intelligently planned, it is quite possible to see 225 species in a year in this vicinity, and I have seen 280 species in all, in the same eighteen-year period. A good May-day list will exceed 100 species and a good day in fall will yield 70 species or better. Why then, it may be asked, go to Central Park, where the variety is so small and the number of species so relatively few. The main answer has already been given. More of the rarer transients will be found in Central Park during May than anywhere else. There is another purely practical reason. The average dweller in Manhattan can only look for birds in the country on Sundays, and on week days it is Central Park or nothing. When we consider that only one or two individuals of the rarer species will occur a season, the chances against their being obliging enough to be present on a Sunday are at least seven to one. These two factors combined demonstrate excellently the advisability of visiting the Ramble at least six mornings a week. Next to Central Park the best place for warblers in this region is Englewood, where I have been going every Sunday during May, year after year. I have seen the Cape May warbler there only six times in twelve years, and the mourning warbler never. In Central Park during the same period I have seen the Cape May warbler more than twenty times, and the mourning warbler twice. But it is a general law of life that it is almost impossible to get

A splendid covert for warblers, thrushes, and sparrows. The swans are a domesticated European variety

something for nothing. Hunting rare warblers in Central Park is no exception to this rule. He who, yawning portentously, lurches into the Ramble two or three times before breakfast some May, expecting to see all the rare transients, will be very rapidly and completely undeceived. The prizes come only to the energetic and the persistent, and what is fairly earned is the more thoroughly enjoyed.

Bird lovers may be divided roughly into three classes. The beginner, to whom all species are new and strange, is advised to begin in Central Park. The difficulties of identification are greatly reduced, when the number of possible species is also greatly reduced. With a hundred species learned the country outside will yield its greater wealth of treasures with less confusion and fewer errors. The next stage in progress is marked by the desire to wander farther afield and gain an acquaintance with as many species as possible, and field trips to special places are undertaken with the main hope of seeing some new rarity, or obtaining a large list. This stage is a necessary and valuable experience, and must be passed before the amateur ornithologist really becomes capable of contributing to local ornithology. The Park has little appeal for such people. But when the making of large lists palls, and the chances of seeing a new species locally have become exceedingly remote the opportunities of the Park as a station for studying that most fascinating phenomenon, the migration of birds, is

urged upon those desiring to make something constructive out of their hobby. Every individual bird can be determined with certainty as a transient, or can be definitely known not to be one, something which is utterly impossible in the country, where there are large numbers of permanent, summer, or winter residents to obscure the issue. Consequently the migration periods of species which nest in this vicinity or which are found throughout the year can be determined with more certainty in the Park.

But there is also an element of sport and enjoyment which no account of bird-hunting in a city park should omit. After all, the satisfaction to be derived from a given course of action is directly in proportion to the expectation preceding it. It is possible to see one hundred species in a day in winter in southern California, and it is practically impossible to see more than forty in the vicinity of New York. Yet I never heard of a local bird lover who abandoned his observations during the winter on the ground that bird life was comparatively meager, or who failed to be delighted at seeing thirty species. His expectations were reasonable and controlled by the known facts. The same philosophy can be applied to advantage in Central Park, and many delightful week-day hours each spring and fall are shared by a band of fellow enthusiasts and friendly rivals. We are as pleased with fifty species in the Ramble as we would be with one hundred in the country. There the crow is utterly despised and ignored; here it is a rare visitor to be greeted with enthusiasm. The morning hours are as cool, the songs are just as sweet.

And then one can never tell exactly what is going to happen next. No two spring or fall seasons are exactly alike. There are lean years like 1924, and very good years like May, 1925, when birds were present almost daily in unusual variety and abundance. There are lean days when almost nothing can be found, and good days, when the Ramble is crowded with multitudes. We have never yet learned how to predict a big flight with absolute certainty. They fail to materialize when the weather conditions seem just right, or they arrive quite unexpectedly. One can never tell just which ones of the rarer species will appear, or when. Once in a great while there are the red-letter days when some bird of extraordinary rarity is detected. I well remember the glowing orange prothonotary warbler which was detected on the "Point" in the lake on May 3, 1908, a wanderer from the cypress swamps of the south. It remained a whole week, sang freely and was absurdly tame, so that it could literally be surrounded by enthusiastic nature study classes, without turning a hair, or more correctly, ruffling a feather. Quite a number of people began to study birds, thanks to the general atmosphere of excitement over this warbler.

Surprising as it may seem for so small an area, nobody ever saw all the species present in the Ramble on any one day, when birds were at all common. The writer, among others, has made repeated and earnest endeavors, but has never succeeded. One pair of eyes cannot hope to equal the combined results of ten or twenty other pairs, as keen or even keener. The following incident is a generalized picture of this state of affairs. I have spent two hours in the Ramble before breakfast entirely alone, and have had a very successful morning. Several new species have arrived over night and one or two rarities have

fallen to my glasses. I return at noon knowing that a group of sharp-eyed friends have spent the entire morning in the Ramble, and I wish to check up on the extent of the flight. We meet and compare notes. I find that they have not seen one or two of my best discoveries. I listen with a certain discreditable satisfaction to their yelps of disappointment, but the situation is immediately reversed, as they reel off so long a string of species, that it seems almost incredible that anyone really interested could have overlooked all of them. Sometimes we scatter in a frantic search for the species missing on our respective lists. Again, if nothing of special note has been reported, we combine forces and go around together. This nearly always results in the discovery of a third group of species, which nobody had seen previously.

I cannot forbear to say a few words in closing about the bird hunter, in relation to his environment, as well as the birds, and more particularly respecting his relations with his fellow citizens, who use the Park for other purposes. It makes me happy to report that in the last twenty years we have gradually become more sane and normal, and we are now almost like ordinary people. Nowadays everybody understands what the bird hunter is about, and is tolerant, or even sympathetic. People will now often stop and ask intelligent questions, or they will try and see the bird for themselves, and even the Park policeman is becoming an enthusiast, the hours on his beat passing more pleasantly than before.

So I can the more cheerfully recommend pleasant and instructive hours of fresh air to city dwellers. Doctors are now advising overworked and nervously fatigued patients to study birds in Central Park. It is a healthy hobby, and with a little skill and experience, the time spent on it can be made of constructive scientific value The lists

Canada geese on the Park lake. They are domesticated birds but perfectly able to fly resulting in numerous reports of wild geese alighting in the Park. Real wild geese are seen about once in ten years flying over at a great height

at the end of this article give a good idea of the possibilities as regards the variety of species. With modifications depending upon the size of the Park and the extent to which its grounds imitate the country, these lists apply fairly well to any park in the northeastern states. The more general reasons for the excellence of a park as an aviary for migratory birds hold true for every city in the United States. The reader is cordially invited to make the experiment for himself.

ANNOTATED LIST OF THE BIRDS OF CENTRAL PARK

A.—Species of Regular or Normal Occurrence (116)

Pied-billed Grebe.—Rare on the park lakes, chiefly in April and October.

Herring Gull.—Common in winter on the reservoirs.

Black Duck.—Descendants of wild birds are resident on the lakes.

Green Heron.—Uncommon, but regular in May, August, and September.

Night Heron.—Seen annually between late April and October.

Solitary Sandpiper.—Rare in May, August, and September.

Spotted Sandpiper.—Common around the lakes and reservoirs in May and August.

Sharp-shinned Hawk.—Every year in late spring and early fall.

Duck Hawk.—A possibility throughout the year on pigeon hunting excursions.

Pigeon Hawk.—Recorded almost every year in late April or early May.

Sparrow Hawk.—Found throughout the year.

Fish Hawk.—Recorded almost every year, chiefly in May.

Screech Owl.—Several resident pairs.

Yellow-billed Cuckoo.—Once or twice a year in late May or early fall.

Black-billed Cuckoo.—Once or twice a year in late May or early fall.

Kingfisher.—Common around the lakes, chiefly in May and August.

Hairy Woodpecker.—Rare in fall, sometimes spending the winter.

Downy Woodpecker.—Permanent resident.

Sapsucker.—Uncommon in spring (April); common late September and early October.

Red-headed Woodpecker.—Rare in May and September.

Flicker.—Common summer resident.

Whippoorwill.—Occasionally found in May.

Nighthawk.—Common all summer, roosting on dead branches.

Swift.—Common all summer.

Hummingbird.—Seen every year in late May and August.

Kingbird.—Seen every year in May and August.

Crested Flycatcher.—Seen every year in May and August.

Phoebe.—Common in early spring and late fall.

Olive-sided Flycatcher.—Rare in late May and August.

Wood Pewee.—Regular in May and early September; one or two pairs breed.

Yellow-bellied Flycatcher.—Every year in late May and August.

Least Flycatcher.—Common in May and August.

Blue Jay.—Uncommon in early May and October.

Crow.—Occurs every year, chiefly in late April and August.

Fish Crow.—Occurs nearly every year, chiefly in May and August.

Starling.—Common permanent resident.

Red-winged Blackbird.—Seen every year in spring and fall.

Baltimore Oriole.—Regular summer resident.

Rusty Blackbird.—Seen annually in April or May, sometimes in October.

Purple Grackle.—Common summer resident, late February to November.

Bronzed Grackle.—Occasional in early spring or late fall.

House Sparrow.—Common permanent resident.

Purple Finch.—Uncommon in spring, common in fall.

Goldfinch.—Common both spring and fall.

Pine Siskin.—Irregular, chiefly in May and October.

Savannah Sparrow.—A few nearly every spring and fall.

White-crowned Sparrow.—Seen nearly every year in May or October.

White-throated Sparrow.—Very common both spring and fall, sometimes wintering.

Chipping sparrow.—Regular in April and October.

Field sparrow.—Common both spring and fall.

Junco.—Abundant on migration, sometimes wintering.

Song Sparrow.—Common on migration; sometimes nesting and wintering.
Lincoln's Sparrow.—Seen every year in May.
Swamp Sparrow.—Common both spring and fall.
Fox Sparrow.—Usually common in early spring and late fall.
Towhee.—Very common, spring and fall.
Rose-breasted Grosbeak.—Common in May, rare in fall.
Indigo Bunting.—Regular in late May, rare in fall.
Scarlet Tanager.—Common every spring and fall
Barn Swallow.—Common both spring and fall.
Tree Swallow.—Seen every spring; common in August.
Bank Swallow.—Seen nearly every year in May
Cedar Waxwing.—Irregular in spring, often common in fall.
Red-eyed Vireo.—A few pairs nest; common on migration in May and September.
Yellow-throated Vireo.—About one a year in May.
Solitary Vireo.—Common both spring and fall.
White-eyed Vireo.—Uncommon in May.
Black and White Warbler.—Abundant in May, August and September.
Worm-eating Warbler.—Seen almost every year in May and August.
Blue-winged Warbler.—Uncommon May, common August.
Golden-winged Warbler.—Rare in May and August.
Nashville Warbler —Common in May and September.
Tennessee Warbler.—Irregular in May; common in August and September.
Parula Warbler.—Abundant in May, common in fall.
Cape May Warbler.—Seen annually in May, August and September in varying numbers.
Yellow Warbler.—Common in May and August, a pair usually nesting.
Black-throated Blue Warbler.—Common both spring and fall.
Myrtle Warbler.—Abundant both spring and fall.
Magnolia Warbler.—Very common in May, common in early fall.
Chestnut-sided Warbler.—Common in May and early September.
Bay-breasted Warbler.—Common in late May and August.
Blackpoll Warbler.—Common in May, abundant in fall.
Blackburian Warbler.—Common in May, uncommon in early fall.
Black-throated Green Warbler.—Abundant in May, common in fall.
Pine Warbler.—Common in April; very rare in fall.
Palm Warbler.—Rare in spring, regular in fall.
Yellow Palm Warbler.—Common both spring and fall.
Prairie Warbler.—Common in May and September.
Ovenbird.—Abundant in May, rare in fall.
Water Thrush.—Common in May, August and September.
Louisiana Water-thrush.—Rare both spring and fall.
Mourning Warbler.—Rare in May and August.
Maryland Yellow Throat.—Abundant both spring and fall.
Yellow-breasted Chat.—Seen every year in May; very rare in fall.
Hooded Warbler.—Uncommon in May and August.
Wilson's Warbler.—Common in late May, rare in fall.
Canadian Warbler.—Very common in May, August and September.
Redstart.—Abundant both spring and fall.
Catbird.—Very common both spring and fall.
Brown Thrasher.—Very common both spring and fall.
House Wren.—Seen every spring in late April and May; rare in fall.
Winter Wren.—Rare in May and October.
Brown Creeper.—Common both spring and fall.
White-breasted Nuthatch.—Uncommon in fall, rare in spring.
Red-breasted Nuthatch.—Irregularly common in fall, rare in spring.
Chickadee.—Uncommon in October, sometimes wintering.
Golden-crowned Kinglet.—Uncommon in April, common in October.
Ruby-crowned Kinglet.—Very common both spring and fall.
Gnatcatcher.—Rare in spring, very rare in fall.
Wood Thrush.—Seen annually in May, and sometimes in fall.
Veery.—Fairly common in May, rare in fall.
Gray-cheeked Thrush.—Common in May and September.
Olive-backed Thrush.—Very common in May and September.

Hermit-thrush.—Common in April, early May and October.

Robin.—Common summer resident.

Bluebird.—Uncommon in early spring and late fall.

B.—Species of Very Rare or Casual Occurrence (75)

Holbœlls's Grebe.—Casual on the reservoir; twice.

Horned Grebe.—Casual on the reservoir; three times.

Loon.—Occasionally noted flying over; once on the reservoir.

Iceland Gull.—Once on the reservoir in winter.

Great Black-backed Gull.—Once on the reservoir in winter.

Laughing Gull.—Casual on the reservoir in late summer.

Common Tern.—Once in late summer.

American Merganser.—Four winter records on the reservoir.

Red-breasted Merganser.—Twice on the reservoir, April and October.

Hooded Merganser.—Once in late November.

Green-winged Teal.—Once in fall.

Wood Duck.—Formerly rare in spring and fall; only one record in the last ten years.

Redhead.—Casual; once.

Scaup Duck.—Casual; twice.

Ruddy Duck.—Casual; twice.

Canada Goose.—Tame birds are resident; wild birds on migration are seen flying over about once every ten years.

American Bittern.—Very rare in spring; five records.

Great Blue Heron.—Casual; three times.

Coot.—Once many years ago.

Woodcock.—Now casual; three times in the last twenty-five years.

Least Sandpiper.—Once in May.

Greater Yellowlegs.—Twice.

Killdeer.—Once many years ago.

Bob-white.—Formerly resident; long since extirpated.

Ruffed Grouse.—Formerly resident; long since extirpated.

Mourning Dove.—Very rare on migration.

Turkey Vulture.—Once.

Marsh Hawk.—Casual; no record in twenty years.

Cooper's Hawk.—Very rare; five times in past eighteen years.

Red-tailed Hawk.—Casual, no recent records.

Red-shouldered Hawk.—Casual, no recent records.

Broad-winged Hawk.—Very rare, only once in past twelve years.

Rough-legged Hawk.—Once.

Bald Eagle.—Twice.

Long-eared Owl.—Four times in winter.

Barred Owl.—Formerly resident; extirpated years ago.

Saw-whet Owl.—Three times in winter.

Snowy Owl.—Once in winter.

Red-bellied Woodpecker.—Once.

Acadian Flycatcher.—Rarely identified in spring.

Alder Flycatcher.—Rarely identified in spring.

Bobolink.—Very rare in May and August.

Cowbird.—Very rare in April and October.

Meadowlark.—Casual.

Orchard Oriole.—Very rare in May.

Pine Grosbeak.—Two winter records.

American Crossbill.—Very rare and erratic visitant.

White-winged Crossbill.—Twice in winter.

Redpoll.—Very rare and irregular in winter.

Snowflake.—Twice in winter.

Vesper Sparrow.—Casual; twice in last twenty years.

Grasshopper Sparrow.—Once.

Seaside Sparrow.—Once.

Tree Sparrow.—Very rare in winter.

Cardinal.—Formerly resident, now extirpated.

Dickcissel.—Once.

Purple Martin.—Only five records.

Cliff Swallow.—About once in five years in May.

Rough-winged Swallow.—Once.

Northern Shrike.—Very rare in winter.

Migrant Shrike.—Once.

Philadelphia Vireo.—Twice in September.

Warbling Vireo.—Now very rare in May.

Prothonotary Warbler.—Three records in spring.

Orange-crowned Warbler.—Once in September.

Cerulean Warbler.—Once in May, once in September.

Yellow-throated Warbler.—Once in spring.

Kentucky Warbler.—Very rare in May.

Connecticut Warbler.—Twice in May; four times in September.

Pipit.—Casual on migration; four records.

Mockingbird.—Casual; five times.

Carolina Wren.—Rare and irregular visitant.

Long-billed Marsh Wren.—Three times in May.

Tufted Titmouse.—Once in May.

If you wish to identify the birds you have seen you will find the Birds of the Vicinity in the West Corridor, Second Floor, of the Museum.

If you wish to know more about our birds, their haunts and habits, when and where they are to be found you will find the information in the illustrated Handbook of 400 pages, by Ludlow Griscom, entitled "Birds of the New York City Region." This may be purchased at the Museum for only a dollar.

DISTRIBUTIONAL LIST

OF THE

REPTILES AND AMPHIBIANS

OF THE

NEW YORK CITY REGION

By G. KINGSLEY NOBLE

Curator of Herpetology

THE AMERICAN MUSEUM OF NATURAL HISTORY

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THE REPTILES AND AMPHIBIANS OF THE NEW YORK CITY REGION

A DISTRIBUTIONAL LIST PREPARED FOR THE LINNÆAN SOCIETY OF NEW YORK

By G. Kingskey Noble

The reptilian and amphibian faunas found within seventy-five miles of New York City, in New Jersey, in the counties bordering the east shore of the Hudson, and on Long Island differ from one another in several particulars. The present list is prepared to call attention to these differences and to suggest gaps in our knowledge which we hope will be filled before many years by the many naturalists now in the local field.

The list is merely a preliminary statement of the general ranges of our local reptiles and amphibians. Exact locality records of practically all our species are greatly desired. It is only when they are brought together that a clear picture of the distribution of our local species can be obtained.

Information as to dates of appearance and disappearance of the species should be of interest to all observers in the local field. Observations on the habits of even the commoner species may prove of great scientific value. This is especially true of the breeding habits which are not well known even for some of our commonest form.

The number of reptiles and amphibians in the local region is not great, and their identifications should offer no difficulty. Convenient keys to the local species will be found in Pratt's "Manual of the Vertebrates of the United States" (P. Blakiston's Son & Co., Philadelphia). Other useful reference books would be: Dickerson's "Frog Book," Ditmars' "Reptile Book," and Blanchard's "A Key to the Snakes of the United States, Canada, and Lower California." There is, however, no book which gives the information most needed

by the New York field naturalist—namely, a full statement of the distribution of our local species.

The following list has been critically read by the Linnæan Society Committee on Local Herpetology and also by Messrs. Wm. T. Davis, G. P. Engelhardt, S. C. Bishop and W. De W. Miller. Further information in regard to the local reptilian and amphibian faunas may be obtained from the Chairman of this Committee or from the American Museum of Natural History.

The abbreviations refer to regions within 75 miles of New York City. L. I. = Long Island, N. J. = New Jersey, and N. Y. = southern New York, exclusive of Long Island.

1. Water Newt (aquatic form), Red Eft (terrestrial form)
   Triturus viridescens (Rafinesque)
   L. I., N. J., N. Y. Red Eft stage absent from L. I. and possibly from other sandy regions.
2. Jefferson's Salamander
   Ambystoma jeffersonianum (Green)
   L. I., N. J., N. Y. Rare. Locality records desired.
3. Spotted Salamander
   Ambystoma maculatum (Shaw)
   L. I., N. J., N. Y. Common.
4. Marbled Salamander
   Ambystoma opacum (Gravenhorst)
   L. I., N. J., N. Y. Not rare.
5. Tiger Salamander
   Ambystoma tigrinum (Green)
   L. I., N. J., N. Y. Rare except at certain L. I. localities.
6. Four-Toed Salamander
   Hemidactylium scutatum (Schlegel)
   L. I., N. J., N. Y. Locality records desired.
7. Red-Backed Salamander, Gray Salamander (two color phases)
   Plethodon cinereus (Green)
   L. I., N. J., N Y. Common.

8. Slimy Salamander
Plethodon glutinosus (Green)
Absent from L. I.; common in N. J. and along the west shore of the Hudson, reported from Staten Island and from Westchester Co. but N. Y. records desired.

9. Purple Salamander
Gyrinophilus porphyriticus (Green)
Absent from L. I.; no definite locality records for our region but very probably found in N. J.

10. Muddy-Spring Salamander
Pseudotriton montanus (Baird)
Recorded from N. Y. Very rare.

11. Red Salamander
Pseudotriton ruber (Sonnini)
Absent from L. I.; only one N. Y. record except those from Staten Island and Rockland Co.; very common in N. J. Breeding and N. Y. records important.

12. Two-Lined Salamander
Eurycea bislineata (Green)
L. I., N. J., N. Y. Common.

13. Long Tailed Salamander
Eurycea longicauda (Green)
Only in N. J. Locality records desired as the species is known from N. Y. north of our area.

14. Dusky Salamander
Desmognathus fuscus fuscus (Rafinesque)
L. I., N. J., N. Y. Common.

15. Mountain Salamander
Desmognathus fuscus ochrophaeus (Cope)
Probably N. J. and N. Y. Additional records desired.

6. Spade-Foot Toad
Scaphiopus holbrookii (Harlan)
Common L. I.; rare elsewhere. Locality records desired.

17. American Toad
Bufo americanus Holbrook
Common N. J., N. Y., absent L. I. and Staten Island. What are its habitat preferences?

18. Fowler's Toad
Bufo fowleri Garman
L. I., N. J., N. Y. Common.

19. Cricket Frog
Acris gryllus (Le Conte)
L. I., N. J. Only one definite N. Y. record, other than Staten Island.

20. Common Swamp Tree Frog
Hyla (Pseudacris) triseriata (Wied)
Only N. J. and Staten Island. Not common.

21. Baird's Swamp Tree Frog
Hyla (Pseudacris) feriarum (Baird)
Often confused with the preceding species. Recorded from N. J., but definite records lacking.

22. Anderson Tree Frog
Hyla andersonii Baird
Pine barrens of N. J. Not rare.

23. Spring Peeper
Hyla crucifer Wied
L. I., N. J., N. Y. Common.

24. Gray Tree-Toad
Hyla versicolor (Le Conte)
L. I., N. J., N. Y. Common.

25. Bull Frog
Rana catesbeiana Shaw
L. I., N. J., N. Y. Common.

26. Pond Frog, Green Frog
Rana clamitans Latreille
L. I., N. J., N. Y. Common.

27. Pickerel-Frog
Rana palustris Le Conte
L. I., N. J., N. Y. Common. Usually a mountain frog (except on Long Island). Habitat records desired.

28. Leopard-Frog
Rana pipiens Schreber
L. I., N. J., N. Y. Common. Usually a salt marsh or coastal plain frog. Habitat records important.

29. Wood-Frog
Rana sylvatica Le Conte
L. I., N. J., N. Y. Common.

30. Sphagnum-Frog, Carpenter Frog
Rana virgatipes Cope
Pine barrens of N. J. Life history information important.

31. Six-Lined Swift
Cnemidophorus sexlineatus (Linné)
Reaching the extreme southern edge of our region in N. J.

32. Fence-Lizard
Sceloporus undulatus (Latreille)
Pine barrens of N. J.; N. Y. (only three locality records); northern records desired.

33. Blue-Tailed Skink
Eumeces fasciatus (Linné)
N. J., a few N. Y. records, others desired.

34. Worm-Snake
Carphophis amoena (Say)
L. I., N. J., N. Y. Rare. Records important.

35. Ring-Neck Snake
Diadophis punctatus edwardsii (Merrem)
L. I., N. J., N. Y. Habitat records desired.

36. Hog-Nosed Snake, Spreading Adder
Heterodon contortrix (Linné)
L. I., N. J., N. Y. Common. Habitat records important.

37. Smooth Green-Snake
Liopeltis vernalis (Harlan)
Common in N. J., rare in N. Y., and L. I. Locality records important.

38. Rough Green-Snake
Opheodrys aestivus (Linné)
Pine barrens of N. J., recorded, also from L. I. Locality records very important.

39. Black-Snake
Coluber constrictor (Linné)
L. I., N. J., N. Y. Common.

40. Corn-Snake
Elaphe guttata (Linné)
Pine barrens of N. J.

41. Pilot Black-Snake
Elaphe obsoleta (Say)
N. J., N. Y. Apparently absent from L. I. Usually a mountain species. Habitat and locality records desired.

42. Pine-Snake
Pituophis melanoleucus (Daudin)
Pine barrens of N. J.; one record from N. Y.

43. King-Snake
Lampropeltis getulus (Linné)
N. J.; possibly N. Y. Locality records much desired.

44. Milk-Snake
Lampropeltis triangulum (Lacépède)
L. I., N. J., N. Y. Common.

45. ?Kirtland's Snake
Natrix kirtlandii (Kennicott)
Possibly in the extreme southern edge of our region.

46. ?Queen-Snake
Natrix septemvittata (Say)
Possibly in the extreme southern edge of our region.

47. Water-Snake
Natrix sipedon (Linné)
L. I., N. J., N. Y. Common.

48. DeKay's Snake
Storeria dekayi (Holbrook)
L. I., N. J., N. Y. Common.

49. Red-Bellied Snake
Storeria occipito-maculata (Storer)
N. J., L. I. Definite N. Y. and L. I. records desired. Rare.

50. Gray Snake
Virginia valeriae Baird and Girard
Only N. J. Locality records desired.

51. Ribbon-Snake
Thamnophis sauritus (Linné)
L. I., N. J., N. Y. Common.

52. Garter Snake
Thamnophis sirtalis (Linné)
L. I., N. J., N. Y. Common.

53. Copperhead
Agkistrodon mokasen Beauvois
N. J., N. Y., absent L. I.

54. Timber Rattlesnake
Crotalus horridus Linné
N. J., N. Y., formerly present on L. I., but now exterminated.

55. Musk Turtle
Sternotherus odoratus (Latreille)
L. I., N. J., N. Y. Common in clear, highland ponds, rare on L. I.

56. Mud Turtle
Kinosternon subrubrum (Lacépéde)
L. I., N. J., N. Y. Common on the coastal plain. Highland records desired, also habitat notes.

57. Snapper
Chelydra serpentina (Linné)
L. I., N. J., N. Y. Common.

58. Spotted Turtle
Clemmys guttata (Schneider)
L. I., N. J., N. Y. Common.
The salt marsh specimens are distinctly rougher than the fresh water specimens.

59. Wood Turtle
Clemmys insculpta (Le Conte)
Common in N. J., rare in N. Y., probably absent from L. I., although there are several records. L. I. records very important.

60. Muhlenberg's Turtle
Clemmys muhlenbergii (Schoepff)
N. J., N. Y., absent on L. I. Locality records desired.

61. Blanding's Turtle
Emys blandingii (Holbrook)
Although this species has been recorded from L. I., it probably enters our region, only in the extreme north. Locality records desired.

62. Box Turtle
Terrapene carolina (Linné)
L. I., N. J., N. Y. Very common on L. I.; not rare elsewhere.

63. Salt Water Terrapin
Malaclemys centrata concentrica (Shaw)
Coasts of L. I., N. Y., and N. J.

64. Painted Turtle
Chrysemys picta (Schneider)
L. I., N. J., N. Y. Common.

65. Red-Bellied Turtle
Pseudemys rubriventris (Le Conte)
Coastal plain of N. J. Rare. Locality records desired.

66. Green Turtle
Chelonia mydas (Linné)
Accidental off our coast.

67. Hawks-Bills Turtle
Eretmochelys imbricata (Linné)
Accidental off our coast.

68. Loggerhead Turtle
Caretta caretta (Linné)
Regular visitant to our coast.

69. Kemp's Turtle
Caretta kempii (Garman)
Regular visitant to our coast.

70. Leather-Back Turtle
Dermochelys coriacea (Linné)
Rare along our coast.

THE HALL OF DINOSAUR

BY

FREDERIC A. LUCAS

THIRD EDITION

GUIDE LEAFLET SERIES No. 70

THE AMERICAN MUSEUM OF NATURAL HISTOR

Horned Dinosaur Triceratops

As reconstructed by Charles R. Knight. In the distance a pair of the contemporary Trachodonts.

THE HALL OF DINOSAURS

By FREDERIC A. LUCAS

A DINOSAUR is a reptile, a member of a group long extinct, having no near living relatives, the crocodiles, though closer than any other existing forms, being but distantly connected; neither are the great lizards froms Komodo Islands, which have attracted so much attention recently under the title of dragons, nearly related.

The name Dinosaur, terrible reptile, was bestowed on these animals because some of those first discovered were big, powerful, flesh-eating forms, but while we are apt to think of Dinosaurs as huge creatures yet there were many kinds of dinosaurs and they ranged in size from big Brontosaurus, with the bulk of half-a-dozen elephants, to little Compsognathus, no larger than a Plymouth Rock chicken.

The Dinosaurs lived mostly during the periods that geologists call Jurassic and Cretaceous, periods of many million years, six at least, more probably nearer thirty. The race started a little before the Jurassic, some 35,000,000 years ago, and came to an end with the Cretaceous about six million years ago. In their day they were found over the greater part of the world, Europe, Asia, Africa, America, and Australia. It was a strange world in which they lived, a world peopled by reptiles, the Age of Reptiles, as the time is called; besides the Dinosaurs there were crocodiles and turtles; flying reptiles, with a spread of wing greater than that of any living bird, and little pterodactyles about the size of a robin; in the sea during one period there were reptiles like porpoises and, later, they were succeeded by those something like great iguanas, but with paddles instead of feet, while with them were giant turtles far larger than any sea turtles of to-day; there were a few birds, some that flew and some that swam, but they differed from existing birds in having teeth.

There were no mammals in this ancient world, or at least only little ones something like small opossums.

There were no Elephants or Rhinos, no Buffalo or Deer, no Lions, Tigers, or Bears. Instead there were Dinosaurs, Dinosaurs everywhere, big lumbering creatures as big as many elephants, wading in the streams and lakes, feeding on water plants, smaller dinosaurs stalking by the water side or splashing into the water and swimming hastily away upon the approach of some big flesh-eating dinosaur looking for his dinner, or supper and little dinosaurs scurrying out of the way.

At the close of the Cretaceous great changes took place in the face of the earth and brought about changes in climate and in animal and plant life.

The reign of reptiles came to an end, the mighty dinosaurs and their little relatives passed away, and the mammals, hitherto few and small, began to increase and multiply until they became the possessors of the earth.

These changes did not take place suddenly but extended over many thousands of years, gradually the mountains rose, the climate became drier and colder, the lakes and marshes dried up, and the reptiles adapted to a warm climate and easy life did not change with them, but fell by the wayside and perished, leaving their bones to testify to their former presence.

Many died on land, where, under the attacks of sun and rain, frost and snow, their bones went to pieces and crumbled into dust leaving nothing to show of their former existence. But some sank to the bottom of lakes or streams, and some were swept into the ocean; in such places they were covered with mud or sand that as ages passed became beds of rock while the bones themselves changed to stone, became petrified, as it is popularly termed.

Millions of years later came man, puny and weak from the dinosaur view point, but possessed of a brain and hand that soon made him the ruler of the earth. And as he gradually increased in intelligence he became interested in learning about the races that had preceded him in time and finding the bones of dinosaurs began to collect and study them and to gather them into places he called museums. And so it came to pass that after millions of years these former lords of creation were brought from their sepulchers and placed in the Hall of Dinosaurs to arouse the wonder of visitors.

While Dinosaur bones have been found in various parts of the earth, yet the places where they are really abundant and accessible are comparatively few in number, the best hunting grounds so far discovered being in Wyoming, Montana, and Alberta. In some localities, like the Connecticut Valley, we know dinosaurs were common because they have left their foot prints on what was once the shore of an arm of the sea, but very few of these bones have been found, they were probably swept out to sea and buried beyond our reach.

THE DINOSAURS

Many books and many articles, mostly scientific, have been written about Dinosaurs, this leaflet deals only with a few of them, those displayed in the Hall of Dinosaurs.

On the right and left of the entrance are two good-sized, lightly but powerfully built, flesh-eating dinosaurs known to science as **Gorgosaurus**. As shown by their build and hollow bones, they were doubtless swift and fierce and preyed upon their smaller, feebler fellows as Lions and Tigers to-day prey upon, Zebra, Antelope, and Deer. The big, strong hind legs, with a stride of ten to fifteen feet, carried them swiftly over the ground, and their great claws were fitted for holding and tearing their prey. The diminutive fore legs, also armed with sharp claws, helped to tear up their food.

Near them are examples of a rather small dinosaur whose legs and general build suggest an Ostrich with a long tail, and called on account of this resemblance **Struthiomimus**. This animal far from being a "terrible reptile" was toothless, and his fingers were long and slender, not at all fitted for tearing anything. It has been thought that they were adapted for carrying eggs which were stolen from the burying places of other dinosaurs, the long, slender legs enabling the thief to run away from any pursuers.

Triceratops, big, lumbering, huge-headed, stupid creature was a plant eater, probably of coarse vegetation. His jaws ended, or began, in a great horny beak for clipping off branches and rushes, and his back teeth were adapted for champing them. These back teeth were arranged in many rows and were all the time pushed upward by new teeth forming below, so that as fast as teeth wore out they were replaced, a point in which Triceratops might well be envied. The fore legs, bowed outward at the elbows, enabled the animal to reach the ground with ease and the big "frill," suggesting a fireman's helmet, was not alone for protection, but served as a counterweight to the head and jaws, so the skull almost balanced on the condyle, or ball joint by which it joined the neck.

Triceratops had numerous relatives who rang all possible changes on their frills and horns, some of the frills being mere margins of bone, some with plain edges, some decorated with star-like points like the head of a giant horned toad; some had, as the name implies, three horns, others like *Monoclonius*, under the window, only one. Triceratops suggests a Rhinoceros, but has no relationship whatever with that animal—it is a case of appearance only, what is called analogy, not homology.

Across the way from Triceratops is a group of Dinosaurs which seems to have been very abundant in their day, **Trachodon** and his relatives, **Corythosaurus**, **Saurolophus**, and others. Among these is

one of the rare prizes that sometimes full to the lot of the collector, a specimen in which a large part of the skin has been preserved, so that we are certain as to the covering of the animal. The reptile is supposed to have died on land, been baked in the hot sun and thens wept into the bed of a stream by a freshet and buried in the sand. What the antelopes

A bit of the skin of a Duck-billed Dinosaur, about natural size

are to Africa, these creatures were to North America, the characteristic animals of the country. They rang the changes in the shape of their heads, which varied in an extraordinary fashion. They were water-dwelling animals with powerful, compressed tails and webbed feet, this last we know from the "mummied" specimen. Like the carnivorous dinosaurs, they were three-toed animals and walked erect; that they did *not* drag, their tails is shown by the fact that there is no groove, or furrow, between the footprints; the tail acted as a balance or counterpoise to the body, and the many slender bones along the sides of the vertebræ show that there were many strong muscles that carried the tail off the ground without any exertion on the part of the animal.

Many of the Dinosaurs which at a much earlier date (Triassic) dwelt in what is now the Connecticut Valley and left their footprints in the sand of time also walked on their hind legs, with their tails clear, and as there was no mark of a tail it is not surprising that the footprints were thought to be those of gigantic birds and so described and named.

Towering above the others, his head eighteen feet from the ground, is **Tyrannosaurus** the well-named King of Reptiles, whose terrible jaws and tremendous claws placed all contemporaries at his mercy, though a too careless attack on Triceratops might result disastrously and **Ankylosaurus** and **Palaeoscincus** might often defend themselves successfully.

Looming up in the distance is **Brontosaurus**, the Thunder Reptile, big-bodied, small-headed, with massive limbs whose joints, in life covered with gristle, indicate that he was largely a water dweller, where the great weight of his body, 25 to 30 tons, would be supported.

The small head and feeble teeth tell that Brontosaurus was a vegetable feeder, and looking at the big body one feels that it must have kept the head busy to supply it with needed nourishment.

Near-by Brontosaurus in **Allosaurus**, apparently turned into a fossil while munching on the tail of a defunct relative of that big beast; looking closely ones sees that the tops of the vertebræ are scored with grooves where some millions of years ago it was feasted upon by some flesh-eating

Allosaurus in the role of a Scavenger feeding upon part of Brontosaurus

contemporary. It is not necessary to suppose that Allosaurus killed the huge creature on which it is feeding, just as there were active, vicious carnivores so there may have been those who played the role of Hyænas and fed upon anything they found dead. Of course it is not at all certain that this particular Allosaurus feasted upon this very Brontosaur, but their skeletons were found within a half mile of one another, so that it is quite possible that they were associated in life as in death.

Two very extraordinary armored dinosaurs are represented by only parts of their skeletons, **Ankylosaurus** which Dr. Lull has called "the most ponderous animated citadel the world has ever seen" had its head and body protected by thick plates of bone, while the tail instead of tapering to a point ends in a great ball of bone.

We can imagine that when attacked Ankylosaurus flattened himself along the ground and wagged his tail. Now the carnivorous Dinosaurs had no big hind toe, such as is found in birds of prey, so while they could

tear, they could only grasp downward and the big claws would find it a difficult matter to get hold of an armour-clad back, and if a leg or tail came in contact with the big knobbed tail of Ankylosaurus it would assuredly be smashed.

Beside Ankylosaurus is the fore part of **Palaeoscincus** whose sides bristled with huge, bony spines and whose back was protected by bony plates so that he too was well able to defend himself.

Perhaps some readers may feel as did the good old lady who said she did wonder how they knew the names of these old animals when they found them, or if not may wonder why they have such long names.

It was long ago discovered that not only did so-called common names mean nothing, but that there would not be enough for all the animals that would be discovered. So a Swedish naturalist, Linnæus, devised the plan of giving every kind of animal two names, the first a general, or generic name, that should be borne by him and his relatives, the other a special, or specific name, that should apply to that particular kind or

American Museum party at Bone-Cabin Quarry, 1899. Seated, left to right Walter Granger, Professor H. F. Osborn, Dr. W. D. Matthew; standing, F. Schneider, Prof. R. S. Lull, Albert Thompson, Peter Kaison. This was a famous locality for Dinosaurs

species. These names, usually taken from the Greek or Latin, as a rule allude to some apparent character of the animal to which they are applied, as shown by those which follow

Allosaurus, leaping reptile. From its supposed active habits in springing upon its prey.

Ankylosaurus, fused reptile. In allusion to the manner in which the bony plates are fused, or ankylosed, with the bones of the skeleton.

Brontosaurus, thunder reptile, so heavy that the earth trembled beneath its tread.

Corythosaurus, helmeted reptile. From the shape of the skull which suggests that of a cassowary.

Deinodon, terrible tooth.

Gorgosaurus, fierce reptile.

Lambeosaurus, Lambes reptile. Named in honor of Dr. Lambe of the Geological Survey of Canada.

Monoclonius, single conqueror. In allusion to the single horn on the nose.

Ornitholestes, bird robber, at one time supposed he might be sufficiently active to catch birds.

Struthiomimus, ostrich mimic. From the resemblance of its skeleton to that of an ostrich.

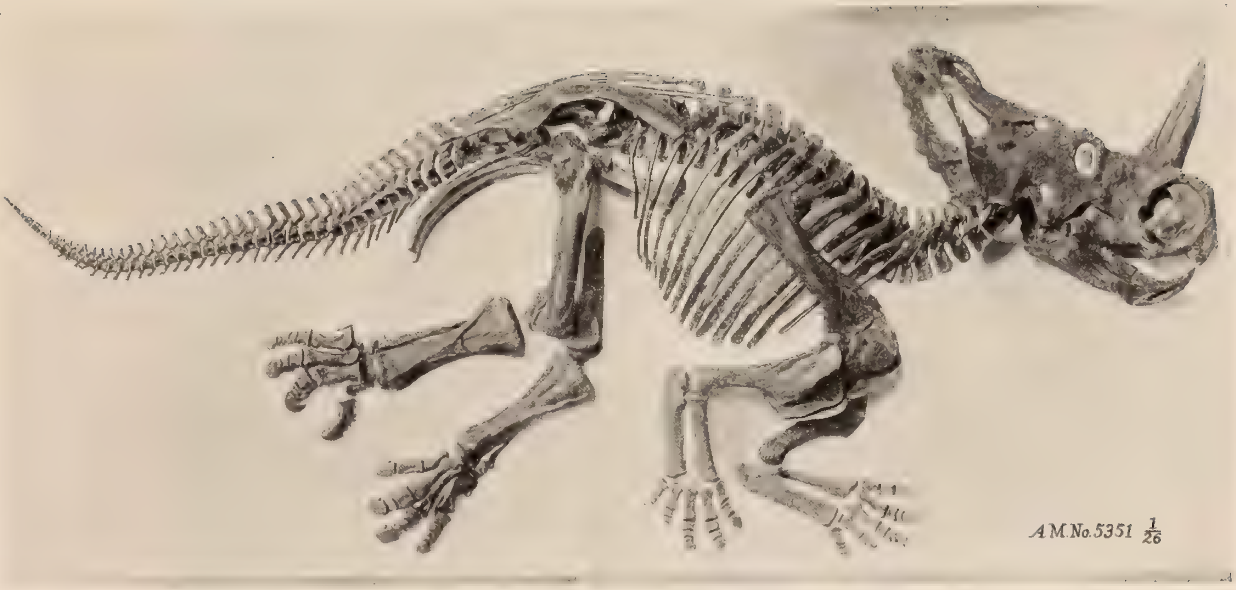
Trachodon, rough tooth. In allusion to the ridges on the side of the teeth.

Triceratops, three-horned face.

Tyrannosaurus, tyrant reptile.

HORNED DINOSAUR TRICERATOPS

A Cretaceous Dinosaur from Montana. Length 24 feet, height 7 feet 9 inches, weight when alive about nine or ten tons, twice the weight of an average Indian Elephant.



Monoclonius

A relative of Triceratops from the Cretaceous of Alberta

Duck-billed Dinosaurs, *Trachodon*

From the Cretaceous of Montana and South Dakota. 33 feet long, stands 17 feet 6 inches high. This was one of the most abundant of the dinosaurs, apparently as common as deer are to-day

"MUMMIED" DINOSAUR TRACHODON

From the Cretaceous Rocks of Wyoming. By a fortunate combination of circumstances a great part of the skin of this animal has been preserved for millions of years. See cut in text.

Duck-billed Dinosaur Trachodon

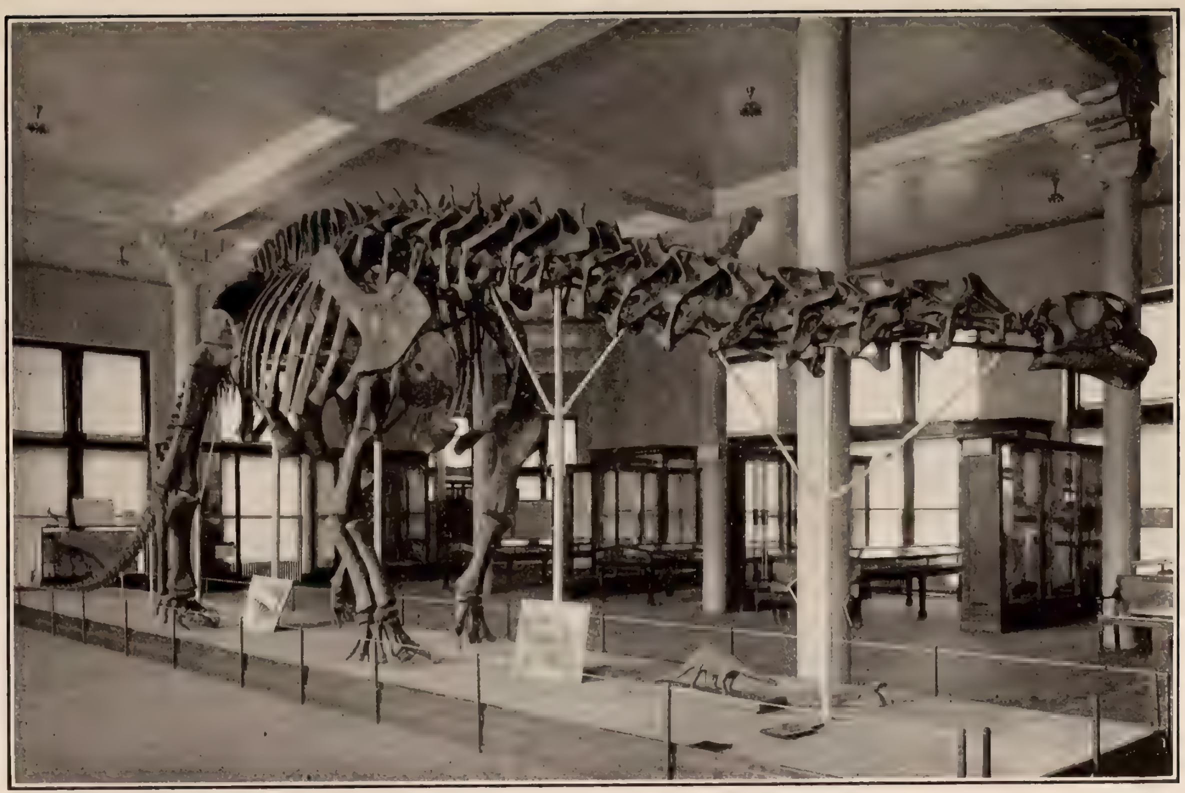
From the Cretaceous of Wyoming, as reconstructed by Charles R. Knight. In walking the tail was carried clear of the ground

The King of Reptiles *Tyrannosaurus rex*

Forty-seven feet long, 18 feet 6 inches high as he now stands. From Montana. Lived in the Cretaceous Period

SKULL OF TYRANNOSAURUS

This skull is four feet long, the largest of the double-edged teeth are six inches long. As in other reptiles the teeth when broken, or worn out were replaced by others; new teeth are seen coming into place in the back of the upper jaw



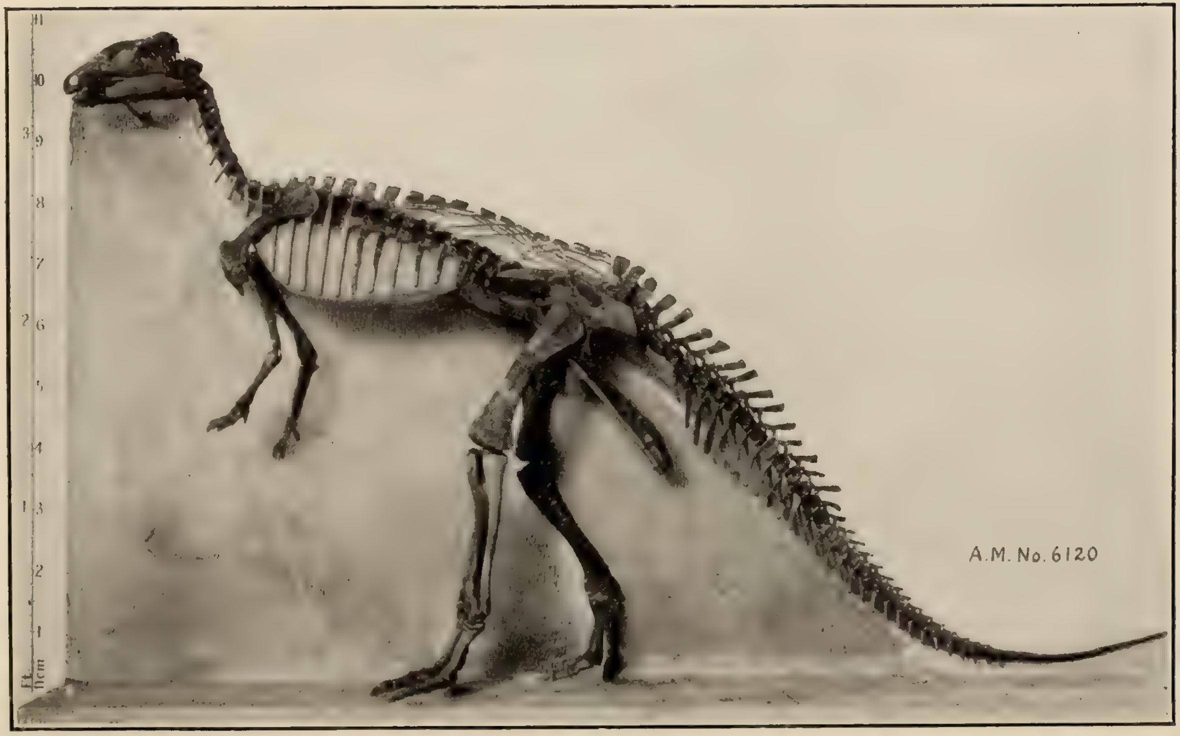
Brontosaurus, the Thunder Reptile

From the Jurassic of Wyoming. Sixty-six feet long, 15 feet high, weighed in life from 30 to 35 tons; a big Asiatic Elephant weighs 5 tons. This was the first large dinosaur to be placed on exhibition; the preparation and mounting of the skeleton occupied the better part of six years.

BRONTOSAURUS, THE THUNDER REPTILE

Reconstruction by Charles R. Knight. Shown as dwelling in the water in which these great creatures are supposed to have passed most of their time, feeding upon water plants

ALLOSAURUS, a Jurassic, flesh eating dinosaur, possibly a scavenger though well provided with teeth and sharp claws



Camptosaurus.—A small Jurassic Dinosaur, A plant eater standing about four feet high

THE AMERICAN MUSEUM OF NATURAL HISTORY

THE MAORIS AND THEIR ARTS

By MARGARET MEAD

GUIDE LEAFLET SERIES, No. 71

MAY, 1928

1. MAP OF NEW ZEALAND.

The areas marked on the accompanying map correspond roughly to the more important groups of Maori tribes.

I. The northern peninsula. Most important tribe,—Ngapuhi.

II. Basin of Waikato River and adjoining coasts. Most important tribe,—Waikato.

III. West Coast area. Most important tribes,—Taranaki and Whanganui.

IV. Bay of Plenty area. Most important tribe,—Arawa.

V. Waiapu area. Principal tribe,—Ngati-Porou.

VI. Urewera country. Tuhoe tribe.

VII. East Coast area. Ngati-Kahungunu.

VIII. South Island. Kau-Tahu tribe.

THE MAORIS

AND

THEIR ARTS

By

MARGARET MEAD

GUIDE LEAFLET No. 71

The American Museum of Natural History

New York, May 1928

CONTENTS

THE MAORIS AND THEIR ARTS

INTRODUCTION

Maori is the name given to the native people whom the Europeans found living in New Zealand at the time of discovery. In language and custom, they are grouped with the other Polynesian peoples who inhabit the Pacific Islands between Hawaii and New Zealand. They are believed to have migrated to New Zealand from Southeastern Polynesia in the twelfth and thirteenth centuries.

Coming to the more rigorous climate of New Zealand from the tropical, unexacting island environment, the Maori had many new problems to solve. He had not brought with him the pigs and fowls which formed an important element of diet in his earlier home. The breadfruit tree, the cocoanut palm, the sugar cane, could not be grown in New Zealand, depriving him not only of an important part of his food supply, but also forcing him to find substitute materials for all the uses to which his ancestors had put palm leaves and sugar cane leaves; for basketry, for thatch, for house blinds, for mats. Where the Polynesians used cocoanut oil he had to learn to use shark oil and berries from the *titeki* tree (*Alectryon excelsum*).

Although in remote times the ancestors of the Maori probably knew of the loom, its use had been abandoned in favor of the simpler process of beating out the bark of the paper mulberry tree to make *tapa*, bark cloth. In the South Sea island cases, and especially in the Hawaiian case, are pieces of *tapa*, examples of the high degree of perfection to which the Polynesians had brought the art. But the paper mulberry tree never flourished in New Zealand, nor was the thin, paper-like *tapa* adapted to the more rigorous winters, so the Maori had to learn to dress flax and weave it into clothing. Although a plant related to that producing the *kava* root grew in New Zealand, the Maori did not make *kava*; the disuse of the ceremonial drink of Polynesia changed the aspect of many of their ceremonies, where eating a sacred food replaced the ceremonial *kava* drinking.

Although they succeeded in domesticating the *kumara* (the sweet potato), the taro, and the yam, the *kumara* was only grown as far south as Temuka in South Canterbury, and taro and the yam no farther than Cook Straits. The more southern population (which in New Zealand means the inhabitants of the colder part of New Zealand) had to eke out a meager livelihood from hunting and fishing and never became very numerous, the population of North Island being almost twenty times as dense as that of South Island.

The inhabitants of different parts of New Zealand developed many local characteristics, owing to such considerations as the presence of workable stone for implements and weapons, a food supply which could support a denser population, etc. The most marked difference lies between North and South Island. Most of the early travelers were struck by the characteristics of the North Island Maori and the beautiful and elaborate carving which has so much in common with the art of the Western Pacific, particularly with the Massim and Sepik River areas in New Guinea, and with the Solomons. North Island carving is distinguished by the use of curvilinear designs, particularly in the form of elaborate spirals; while South Island carving is simple and prevailingly rectilinear. Most of the material in the Museum is from the North Island Maori and differs strikingly from the material culture of the other Polynesian groups represented in the hall.

The Maori were divided into family groups, several of which united together formed a *hapu* or local group; while a number of *hapu* constituted an *iwi* or tribe. They lived in fortified villages, surrounded by a stockade or several stockades of tree trunks bound together with sturdy vines. One tribe might be scattered about in many villages. Each village had its own chief, who with his near relatives, both male and female, constituted the local aristocracy. The highest honor was reserved for the *Ariki*, the sacred high chief of the tribe, the eldest son of the eldest son of the highest family, who traced his descent back to the gods and was held in extreme respect and awe. Next to the chiefs ranked those who possessed great special ability as priests, diviners, carpenters, tattooers, or warriors, and beneath them came the landless gentlemen, who nevertheless were too haughty to carry loads upon their backs when the work could be delegated to a woman or a slave. The slaves were prisoners of war, who, carried away into a strange land, were without prestige because their deified ancestors were believed to have entirely disowned them.

The religious life of the Maori was intimately bound up with the idea of taboo, the idea that certain persons, places, acts, were sacred and dangerous. The imposition of taboos for the protection of the food supply or the building of a canoe, and the lifting of these taboos was the work of the priest. The priests were not organized, they were priests of occasions, a birth, a marriage, a harvest, and served the separate deities who presided over the forest, the sea, the traveler, according to the demands of the particular event. A priest's training involved a long apprenticeship during which he was taught esoteric lore and all the

prescribed ceremonial procedure and long chants which he needed in his priestly office. In addition to the invocation of the high gods, the Maori magician and indeed the ordinary Maori as well lived his whole life in constant reference to the ghosts, particularly the ghosts of his ancestors. These ancestral ghosts were believed to have great power of assisting the living, and to exercise a jealous watchfulness lest their descendants break any of the tribal taboos.

Even before he obtained European tools the Maori produced works of art which rank very high in the woodwork of the primitive peoples of the world. The high esteem in which the artist was held and the fact that work dignified rather than demeaned a chief probably had a great influence in producing such beautiful craftsmanship. With the introduction of steel tools, it was no longer necessary to take great pains; the poorest workman could carve more quickly with the new tools than a virtuoso with the old ones. A great deal of inferior work was produced: a sample of such work is the storehouse in the center of the hall. In this house glaring color and mechanical, stereotyped decoration have taken the place of the rich color and highly stylized, but lovingly executed work of the older artists.

WORK IN GREENSTONE

Maori art owes much of its individuality to the existence in New Zealand of *nephrite*, a form of jade usually referred to as greenstone. It was found only on the South Island and the northern Maori had to obtain it by raids or through barter. Even the smallest pieces were greatly valued and the fragments of a large greenstone object which had been broken were reworked into ear pendants and shoulder ornaments.

The greenstone—of which the Maori distinguished many varieties according to color and relative translucency—was found in western river beds either as pebbles, which could easily be carried away or as boulders, like the large one on which the Maori figure stands, which had to be broken up into workable pieces by the use of heavy stone mauls. The broken pieces were sawed to the required dimensions either by blades of trap rock or by thin sheets of sandstone. The process of polishing was carried out by movement back and forth on a hollowed sandstone slab, into which water was allowed to drip steadily from a suspended calabash. For making holes a pumpdrill was used, very similar to the drill exhibited in the Samoan case, but lacking the rigid arm. Chert, flint, or quartzite drill points were used; and the hole was drilled first from one side, then from the other. The tubular drill point was unknown, but it is believed

that a wooden point was sometimes used, requiring the aid of sand and water. Most of the processes are illustrated in the greenstone exhibit.

Although most artifacts made of greenstone were also manufactured in other materials, there are two classes of objects characteristically made in greenstone—weapons of two types, and various ornaments, the most famous of which was the *hei-tiki* (Fig. 2). The weapons are described in a later section. As adze blades of greenstone were frequently perforated and worn around the neck as ornaments, when not in use, students of Maori art feel that the peculiar grotesque form of the *hei-tiki* is the result of the artists' attempt to impose the shape of the adze blade upon the human figure. Similarly the ear-drops may be traced to the custom of wearing small greenstone chisels and gouges as ornaments, while the crescent-shaped ornament has an ancestor in the bone needle, worn suspended from the shoulder. Two important forms of greenstone ornament, the *peka peka*, or bat-shaped form, and the spiral-shaped *manaia* are not represented in the Maori collection. The evolution of these various greenstone objects from tools to ornaments is probably in great part attributable to the use of a precious stone as material for implements.

2. HEI-TIKI. Grotesque human figure carved from greenstone.

Greenstone plays a major role in Maori myth and legend. A characteristic tale explains the curious translucent quality of the form of nephrite known to mineralogists as *bowenite*. Tamatea, a famous mythical navigator, was deserted by his wives, their canoe capsized, and they were turned into blocks of greenstone. Tamatea wept so copiously over one of these blocks that his tears penetrated the stone, and gave it the quality which the Maori name *tangiwai*, or "tear drops."

Greenstone ornaments and especially *hei-tiki* were kept in memory of dead friends and ancestors and ceremonially wept over by mourners. Greenstone weapons were cherished through many generations and were believed to have been endowed with stupendous power derived from the famous chiefs who had used them, and the battles in which they had played a part. They were used in the ratification of treaties and as a ransom price for a life of a captive or the head of a dead chief.

As they made their most valued weapons of greenstone, so also the Maori found it their best figure of speech for the blessings of peace, which they called their "greenstone door."

WOODWORK

Although the Maori showed his skill as a wood carver in the decoration of every object which he used, digging-sticks and pigeon snares, small wooden boxes for storing feathers, adzes, clubs for war and display, his finest work is found in the decoration of war canoes and the great carved communal houses which were the pride of a northern Maori village.

The great trees which were to be used for the body of a canoe, or the ridge pole of a house, and from which the decorated house slabs and side strakes of a canoe were to be hewn, were sometimes selected years before they were to be used, and space cleared about them as a sign that they were already dedicated to a particular purpose. Months before the work was to start crops were planted near the trees, which might be miles from the village. When the crops were ready for the harvest, the chiefs, the carpenters, their families and the slaves who were to do the bulk of the rough work, all moved into temporary houses near the selected trees. A ceremony in which the tree was symbolically struck with a leaf shaped like an adze, and a sacred fire kindled from the first chips cut from the tree, removed the sacredness of the tree and reconciled Tané, the god of the forests, to the loss of one of his children. Cutting the great *kauri* pines was slow work—a scarf was first cut and then part of the wood below it was charred with a carefully tended fire, after which the charred timber was hacked out with stone adzes. Burning and adzing were repeated until the tree fell. In regions where good stone for tools was not available fire was used more extensively. Though the wooden wedge was known to the Maori, he had no timber which would split like the white cedar of the Northwest Coast. Instead he had to hew a log down to the required thinness. Hauling the great logs for many miles over rough trails and through steep gulches was accomplished by means of stout

ropes and a series of wooden skids. Hauling chants with stanzas of long words for slow hauling and short words for quick, kept the hauling crew working in unison and with spirit.

In the village, building either a house or a canoe was also a sacred process. No woman might approach the scene; dogs were tied up for fear their intrusion would profane the work; and no food could be cooked

a

b

Fig. 3. WOODEN BOX USED FOR STORING FEATHERS. a, Lower surface of box, visible when it is suspended from the roof; b, Lid.

on a fire burning the chips from a sacred carving. The carving of a house or canoe might take years to complete, as it was necessary to work very slowly for fear that the wood would crack. The finishing touch was given to house or canoe by a coat of red paint. The parts to be painted were carefully cleaned, sized with the juice of sowthistle and a native shrub, and then painted red with a mixture of oil and burnt ochrous earth, or black with a mixture of oil and soot. The paint brush was of flax fiber, except for the very delicate work, when a stiff bird feather was used.

Houses

The functional division of houses was within the village group rather than within the household, even the individual cook-houses were sometimes united in groups. The great carved houses were sometimes classified as council chambers, sacred houses for the instruction of the young men, guest houses, and houses where the whole tribe slept in time of war. Storehouses were highly decorated and very taboo. Special houses were erected for the initiation of the chief's son into the priesthood and for the birth of a child of rank. But a large number of specialized houses within the household establishment does not seem to have occurred, although chiefs had separate houses for their respective wives. Storehouses were tribal, the possession of the chief, or sometimes individual in the case of the rough, half-sunken house.

Maori houses present a strong contrast between the elaborate houses of assembly, which were beautifully constructed and highly decorated, and the dwelling houses, in which the people—even the chiefs for whom the great houses were built—lived. The essentials of the framework, however, were the same for all these houses, except that in the poorer ones the broad barge boards were sometimes missing. The window, placed beside the door, seems to have been present in even the smallest houses. The groundplan was oblong, the ends gabled, the sides low under the projecting eaves. The low doorway and window aperture opened out onto a veranda. The smallest huts were six to ten feet long and five to eight feet high. The ridge pole was attached to or inserted in two end posts, forked to receive it. Small sticks were fastened to the frame with flax withes; over these was laid a covering of rushes and an outer thatching of spear grass. The better houses were lined with bark and some of them were sunk a foot or two below the surface-level of the ground. The roof, which sloped in an angle of between thirty and forty-five degrees, projected at each end to form a veranda; light poles were placed over the thatch to keep it in place. These small houses contained fireplaces also. Indeed, there were no distinctions between these houses and the great carved houses, except in size, choice of materials, and decorations. Still ruder huts, only thatched on the windward sides, were used by travelers. Canoe houses were long and sometimes presented a vaulted appearance. The ceremonial storehouses were raised on posts and their small doors were contracted at the top.

But the main effort and ingenuity of the Maori was expended on the *whare whakaira*, or carved house (Fig. 4), which was often built as a memorial of some great event, such as the birth of an heir to the principal

chief. These houses varied in height from twelve to twenty feet. The main weight of the ridge poles was borne by two heavy posts, the rear one slightly higher than the front. A central pillar, lighter than the end posts, supported the middle of the ridge pole. These end posts might be either slabs or whole trunks of trees. The ridge pole was about ten feet longer than the house. It was fastened securely to the supporting posts and to the rafters by lashings and wooden pins.

Fig. 4. A FORTIFIED VILLAGE, showing highly carved storehouse and carvings on the tops of the palisade posts.

The groundplan of the house was squared by measuring the diagonals. The side posts, which were of such height as to give the roof a pitch of about thirty degrees, were graduated to correspond to the slope of the ridge pole. They were heavy planks, one to three feet wide, and three to nine inches thick, with rabbetted edges and a semicircular depression in the top to receive the rafters. They leaned slightly inward and were buttressed behind by stout pieces of rough timber which were lashed to eyes in the upper ends of the slabs.

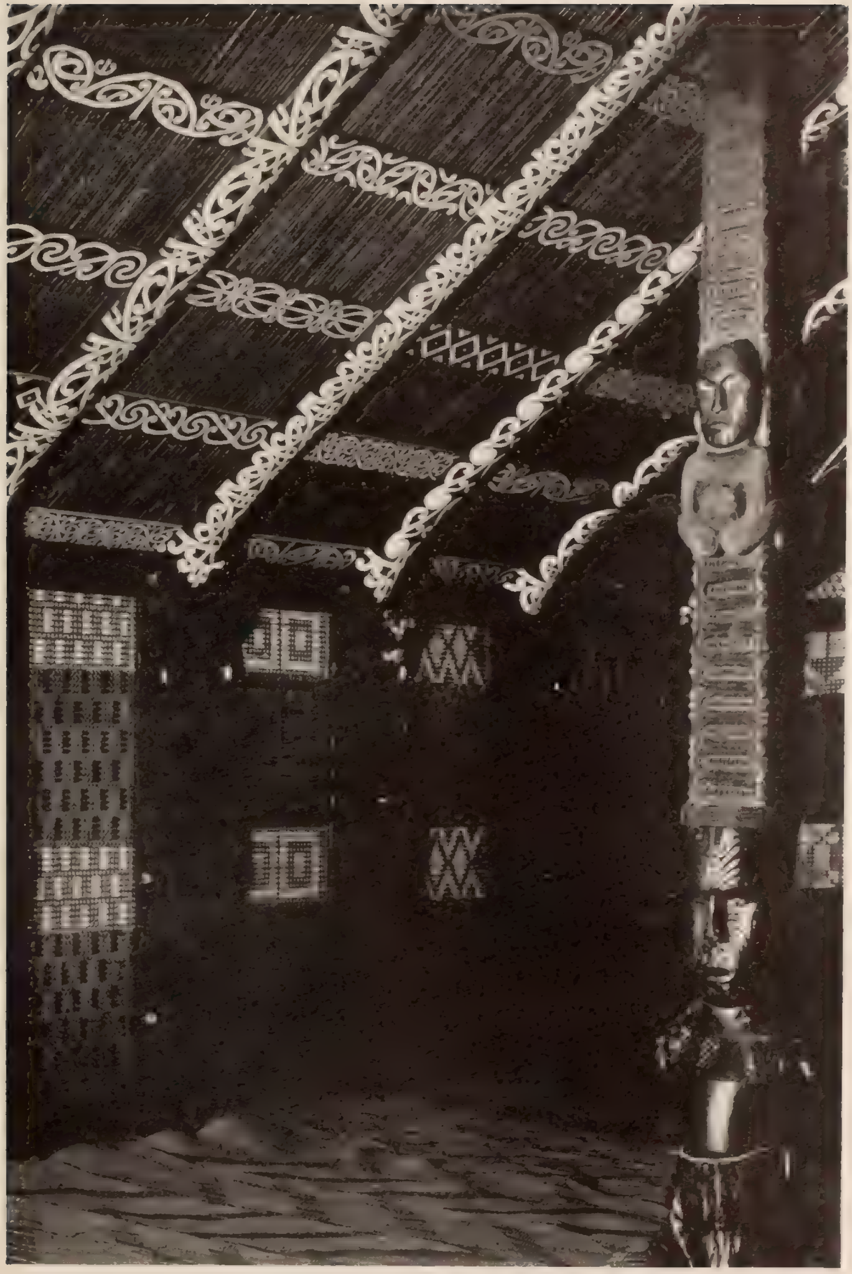


Fig. 5. INTERIOR OF A RECONSTRUCTED HOUSE

A slender stringer ran the length of the house and was lashed to notches or holes in each slab. A wall plate, a board set on its edge, extended from one corner post to the other. Each end slab was lashed to this plate. A skirting board was formed by placing slabs in the intervals between the side slabs. The rafters were cut into a tongue to fit the depression in the top of the side slabs and were lashed to them securely. Horizontal battens were lashed to the rafters and a trellis work of reeds covered these. The front of the roof was finished by heavy boards, which rested on similar vertical facing boards, placed at the front edge of each side wall. The ends of these barge boards projected beyond the house walls and were carved in a conventional filigree pattern.

The door was seldom more than two feet wide and four feet high. It consisted of a slab of wood about two inches thick, which slid along a grooved threshold into a recess built into the wall. The threshold was a piece of timber, about twice the width of the door and about a foot thick. Side jambs rested on this threshold and projected beyond it in each direction to form a molding. The window, about two feet square, was similarly constructed. It was usually so high that a man, sitting, could barely see out.

The wall spaces between the side slabs were filled with flax mats, or with reed battens; the horizontal laths, one-half inch to an inch wide, were lashed to the vertical reeds with colored grasses (Fig. 5). Bunches of bullrush leaves were sometimes inserted for warmth. Further layers of coarse grass completed the thatch. Horizontal poles, vines, or thick ropes, kept the thatch in place and sometimes several of these were placed one above the other in different layers. The ridge pole was bonnetted by a row of fern fronds, or by a thick bundle of long grass, bound over the rear end of the ridge pole and securely lashed to the ridge pole and rafters.

As Maori houses were not built on stone foundations the floor was simply beaten earth, strewn with rushes and ferns. The bed spaces on either side of the door were filled with ferns, and marked off by planks pegged to the floor. The fireplace was a hollow square enclosed either by a row of stones or by wood.

Each family group of houses was surrounded by a fence made with posts planted in the ground, to which horizontal rails were securely lashed. The whole village was surrounded by a large fence of this character, with periodic large posts carved to represent a defiant warrior. The smaller posts were notched at the top so as to resemble a human head. Inside this fence there was sometimes a lighter fence and within these excavated earthworks.

Fig. 6 Fig. 7

Fig. 6 CARVED HOUSE BOARD

7. WOODEN FIGURE USED TO DECORATE A CARVED HOUSE

When the house was finished, it had to be formally consecrated. In this ceremony the priest tied a sacred shrub to the back center post and held a bundle of sacred shrubs in his hand. The charms followed a definite order; the first to propitiate Tané; the second, at which the priest ascended the roof, was to remove the taboo from the carver's sacred instruments and from the wood carved into images of the gods. Here the priest struck the various carvings of the house with the shrub which he held in his hand. The third incantation was an appeal to the gods to make the house warm. The whole ceremony was known as "binding the *maro* (girdle) of the house." The priest then entered the house by a window and opened the door. The threshold was first crossed by three women of rank, so that food might be brought into the house with safety, and the ridge pole prevented from sagging.

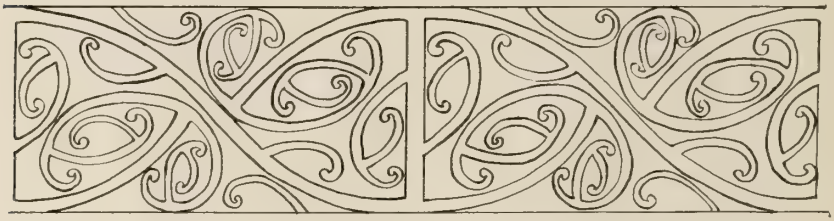


Fig. 8. DESIGNS PAINTED ON THE RAFTERS OF A HIGHLY DECORATED HOUSE. (After Hamilton.)

Human sacrifices were offered at the building of a great house or the fence of an important *pa* (fortified village). In the latter case, a slave was buried under one of the posts. In the former, a member of the tribe was killed, sometimes the favorite child of the chief, the heart was cut out and eaten, and the body buried beneath one of the posts. Occasionally, a distinguished captive was sacrificed thus.

The decoration of the Maori house can be subdivided into carving, rafter painting, and reed work. Sometimes the carving was painted, especially in the case of the heavily carved slabs over the door and window, and on storehouses. When carving did occur in ordinary dwellings it was on the barge boards, the vertical facing boards, and sometimes on the broad piece of timber which faced the front of the veranda. A carved face was placed over the junction of the barge boards and occasionally a human figure placed above this. Storehouses were carved on the whole outside surface. Each separate panel of wood was treated as a decorative unit.

The outside was carved as described above, more elaborately in the case of the large houses. The slabs (Fig. 6) were carved on the inside in high relief into conventionalized human figures. A small human figure was carved in the round at the foot of the center pole. The panels (Fig. 7) between the side slabs were decorated with reed work in elaborate step and checker patterns. These were occasionally modified in an attempt to approximate to the designs of the slab carvings. The rafters were painted in red and white curvilinear designs (Fig. 8). Inlaid haliotis shell decorated the carvings.

The style was characterized, as in the case of canoe carving also, by extensive use of the double scroll, combined with conventionalizations of the human figure. There was a tendency toward intricate incidental decoration and towards treating the part of the object decorated as the unit. House carvings were occasionally decorated with feathers. Ornamental shrubs were sometimes planted around the houses.

Canoes

The only type of Maori canoe of which we have a full description is the single war canoe without an outrigger. Tasman, whose principal stay was at South Island, reports only double canoes, and in 1770 Cook speaks of some canoes being joined together and of the use of outriggers. But in 1840 Pollack, a most careful observer, could say that outriggers were unknown in New Zealand. The early double canoes were said to have been either connected by cross bars which left from two to two and a half feet between the hulls, or to have been only thirty inches apart. These early outrigger canoes, according to the descriptions in the mythology, were built of several boards lashed together, rather than the single strake characteristic of the historical type of Maori canoe, and carried platforms on which awnings were erected. The Maori also possessed a raft-like craft, constructed of bullrushes, similar to that found in the Chatham Islands.

The typical Maori canoe of historical times was built on the dugout plan. The keel was usually hewn from a single tree, occasionally the stern or prow section of the hull was dovetailed on, and an immense strake fifteen or twenty inches wide produced the desired height. These side strakes were lashed to the keel with cords of flax, (the lashing being visible on both sides), and caulked with bullrush down. The seams were covered with battens which were also very long and jointed only once or twice. The stern and bow pieces were hewn out of single blocks of wood and attached separately. Carved braces were lashed across the canoe and

Fig. 9. CARVED STERN PIECE OF A WAR CANOE. (Reproduced through the courtesy of the Dominion Museum.)

a grating was fastened along the bottom of the canoe on which the rowers knelt. The sails were triangular, the largest canoes carrying two. The paddles were from four to five feet long and usually leaf-shaped, tapering to a point, and many variant forms occurred.

The decoration of Maori canoes falls into two classes, permanent and temporary. The permanent decorations were both carved and painted. The most elaborate vessels were richly carved, while the small fishing canoes were often merely painted. The bow and stern pieces were carved from single blocks of wood and the positions of the human figures they embodied were carefully stylized. The stern piece was from six to fifteen feet high and about fifteen inches across and rose almost perpendicularly; the bow piece was from six to ten feet long and about two feet across. At the base of the stern piece was a small carved figure, looking into the canoe, and above this at the termination of the two strengthening ribs was carved a still smaller figure. The whole stern piece was carved in a delicate filigree pattern of double spirals (Fig. 9). The figure-head consisted of a human figure, facing forward, and a mid-rib running back from the figure, carved in the same elaborate filigree as the stern piece. Behind the transverse slab terminating the filigree there was often a small human figure facing the canoe. On the flat part of the bow piece, beneath the filigree, lay the prostrate figure of Maui, a mythical hero. This figure-head was occasionally constructed of two pieces; the vertical mid-board was then grooved into the block. The thwarts and strakes were carved also. The second class canoes had a figure-head with protruding tongue which was less elevated than in the case of the war canoes. The forward and after sections of the body of the canoe were elaborately decorated with painted spirals and patterns resembling those of the thigh tattooing in red, black, and white. The second class canoe was painted red, and the third class, which boasted neither top sides nor carved stern and bow piece, was often painted. The battens which covered the seams were painted black and decorated with white feathers. The model in the American Museum has pearl shells inlaid in the carved work.

The temporary ornaments consisted of feathers fastened to ropes, which streamed from the top of the stern to the surface of the water. The prow was ornamented by two long curving wands, resembling antennæ, tufted with albatross feathers.

The Museum has one very fine figure-head (Fig. 10) which shows the beautiful effect which the carver obtained when working within a strictly delimited convention. The Maori used two types of figure-

Fig. 10. CARVED CANOE PROW

head; the Museum specimen is of the more usual type, with the two large scrolls as the basic motifs of the filigree, and the grotesque figure with protruding tongue and arms extending backward. The stern piece on exhibition shows the characteristic strengthening of the filigree by the two curved ribs surrounded by filigree work of small scrolls. This is an unfinished piece: a completed stern has fine detail carving on the surfaces here left undecorated.

A division of Maori canoes by function or by type of decoration produces identical classifications. The war canoes were most fully and elaborately carved; those used for traveling and fishing were plainer,

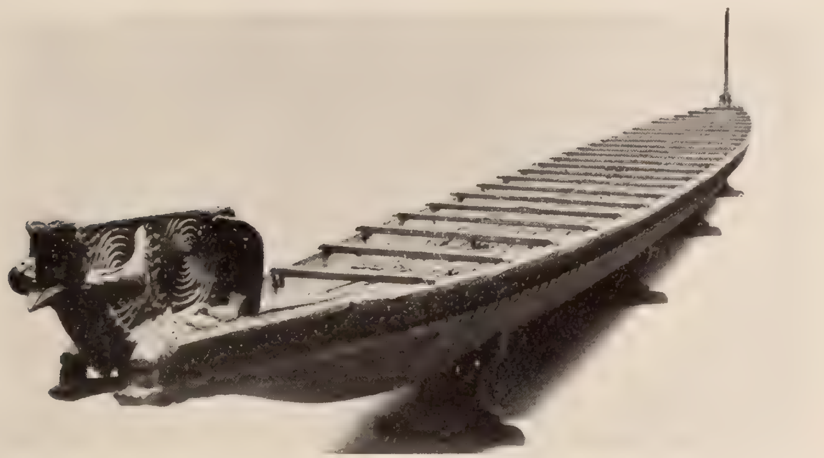


Fig. 11. WAR CANOE named *Te Toki a Tapiri*, Tapiri's Ax. (Reproduced through the courtesy of the Auckland Institute and Museum.)

with a figure-head of a human face with protruding tongue. There were rougher canoes, usually uncarved but sometimes painted. The largest canoes were built for war, but the other two types were not distinguished as to size.

The hull of the canoe was hollowed out inland in the forest. The wood was slowly burned away until the hollow approached the desired size, when the use of fire was abandoned, and the workers proceeded more cautiously with adzes alone under the careful supervision of an expert. When the roughing-out process was complete a great feast was spread and the woman of highest rank in the tribal division mounted the canoe and ceremonially ate the food.

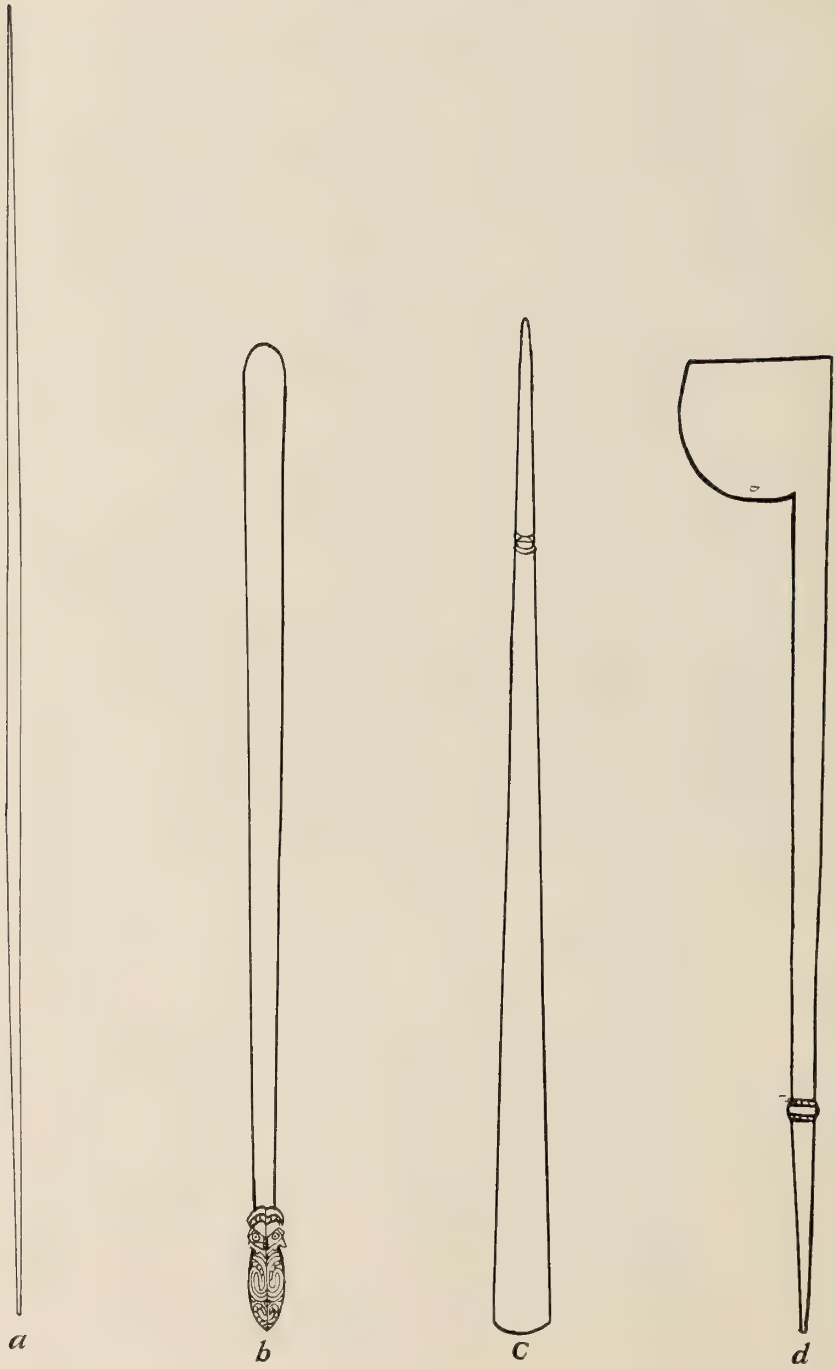


Fig. 12. WOODEN WEAPONS. a, *Tao*. b, *Hani*. c, *Pouwhenua*. d, *Tewhatewha*.

After the hull had been safely hauled to the village, it was sheltered in a shed built for the purpose. The men who worked in it wore special garments woven for them by some old woman of rank. These garments were left in the workshop for fear chips of the sacred wood might be accidentally carried away and contaminated.

Before launching, a priest performed a ceremony to divine the fortune of the canoe. A special shrub was consecrated for this purpose and then pulled up; if the roots were unbroken, the canoe would be lucky. The figure-head of the canoe was struck with this shrub to remove the taboo, so that all the people might use the canoe without danger to themselves; a woman of rank again mounted the canoe and in future a woman might use it with safety. Sometimes a human sacrifice was made, a relative of the chief volunteering for the purpose. If no human sacrifice were made, the heart of a sparrow hawk was offered to the gods in its place. Then a priest chanted a special ritual over the new vessel, placing it under the care of the gods. Sometimes the people chanted a welcome to the new canoe. One such welcome ran, "Come hither O Tané, let us go forth on the waters of *Pikopiko-i-whiti*, that you may be observed of all persons. 'Twas I who went and brought you hither from the great forest of Tané."

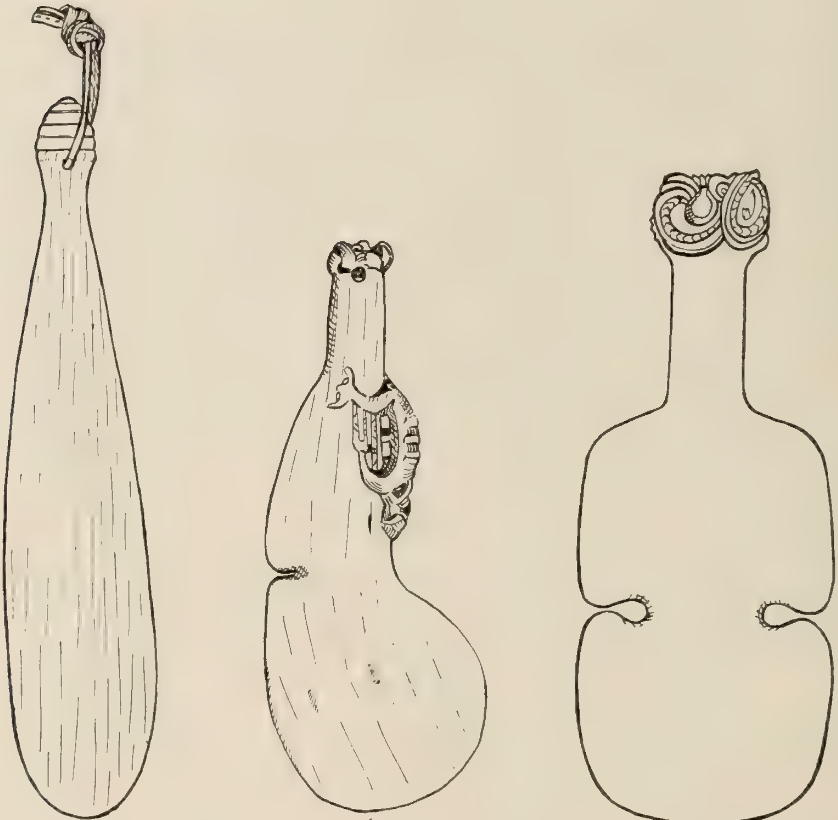
WEAPONS

The principal weapon for actual warfare was the *tao* or spear (Fig. 12a) made of a single piece of hard polished wood. The common form was four to six feet in length; less usual types, measuring twelve to fourteen and sometimes as much as forty feet, were used by several men as ramming rods. These longer spears (*huata*) had a rounded knob and a decoration of dog hair on the end. Other spear forms were barbed on one or both sides with the species of the sting ray, or had two or more points. Some tribes used a short dagger of whale bone.

The famous two-handed clubs are of three main types. The *hani* (Fig. 12b) is characterized by the carving at the butt end representing a human tongue ornamented with scrolls. The *hani* was decorated with a circle of cream-colored dog's hair, above a band of scarlet parrot feathers woven into a ground work of flax fiber.

The blade of the *pouwhenua* (Fig. 12c) is wider than that of the *hani* and the tongue motif is missing, but the handle is similarly decorated below the grasping point with a band of carving representing, often in a much degenerated form, two human faces. It was never decorated with feathers or hair.

The blow dealt by either *hani* or *pouwhenua* was delivered with either edge of the blade. In close hand-to-hand fighting, when an opponent had gotten within the guard, the pointed end of *hani, pouwhenua,* or *tewha tewha* (Fig. 12d) was used like the bayonet. But the



a b c

Fig. 13. THRUSTING WEAPONS. a, *Mere.* b, *Waka-ika.* c, *Kotiate.*

blow of the *tewha tewha,* the ax-shaped club, was delivered with only one edge, the sharpened straight edge parallel with the handle, the ax-shaped expansion merely added weight to the blow. Where the head joins the blade a bunch of feathers was tied through a small hole with a binding of flax. The *hani* and the *pouwhenua* are both forms of one type of weapon, the divergence probably being a local phenomenon; but the *tewha tewha*

is allied to other forms found in the Pacific—to the bent paddle-shaped clubs, one of which is exhibited in the Solomon Islands case and the flaring center-ribbed club of Niué.

Patu is the name given to a group of thrusting weapons made of greenstone, whale bone, and wood, all of which are characterized by a narrow neck expanding into a flat blade with a cutting edge at the distal end of the weapon. The weapon was secured to the wrist with a thong of flax or leather; the blow was delivered at close quarters, with the uplift stroke toward the opponent's temple.

There are two chief types of variation in the *patu*, from the simple symmetrical blade of the *mere* (Fig. 13a) to the indented form called

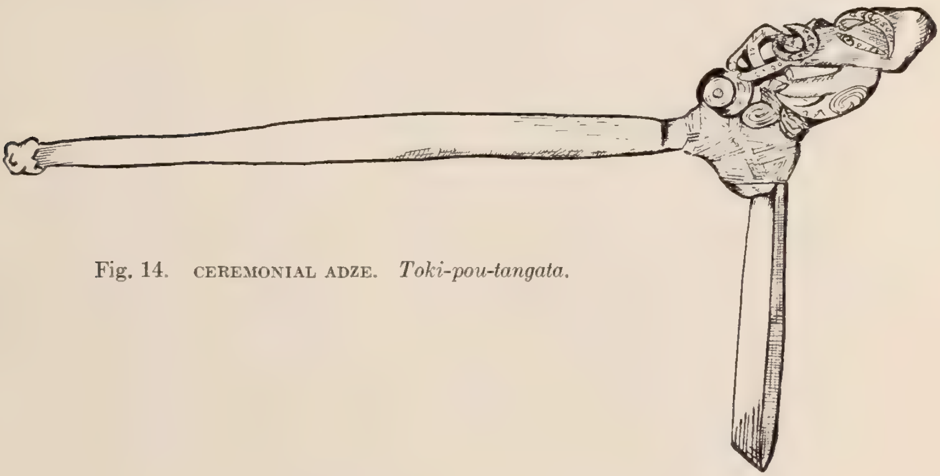


Fig. 14. CEREMONIAL ADZE. *Toki-pou-tangata.*

kotiate (Fig. 13c), of which there is an example in wood in the case of weapons, and the *waka-ika* (Fig. 13b) in which one cutting edge has vanished and a carving of a grotesque human figure has taken its place. The other variation is in the handle, developing from a simple perforation for the thong to an elaborate representation of the human head.

It has been claimed that all of these forms are local New Zealand developments of the adze blade, which occurs as a weapon in the extremely beautiful form of Fig. 14. The original location of the cutting edge was retained and the hand grip developed from the grip used in lashing the adze blade to a handle.

The ceremonial adze (Fig. 14), called a *toki-pou-tangata*, was characterized by the greenstone blade and the carved handle which carries a

Fig. 15. LOOM SHOWING STAKES AND METHOD OF SUSPENSION OF WEB. (Reproduced through the courtesy of the Dominion Museum.)

highly conventionalized decoration, the bird-headed man swallowing a snake.

TEXTILES

The Maori art of weaving is believed to be a local development havings its origins not in the Maori's memory of a loom used before the Polynesians migrated into the Pacific, but rather in the processes of plaiting pandanus, hibiscus bark, and other basketry materials into mats and baskets. The inhabitants of other of the Pacific islands brought this plaiting to a high degree of perfection: notable examples are the "fine mats" of Samoa, worn as clothing on ceremonial occasions, and the famous bed mats of the Hawaiians. But these were all plaited without even the most primitive form of loom. The Hawaiians also brought the art of netting to a high point of development, as may be seen in the foundation of the feather cloak exhibited in the center of the hall. The two twined weft, a true basketry technique, appears in garments from the Hervey Islands and the Tuamotus, and the Samoans use the support afforded by fastening the weft strand with which they begin their grass skirts to two firm supports—the waist of the worker and a house post.

But it remained for the Maori to form a very simple loom (Fig. 15) by planting two upright stakes in the ground and stretching a supporting weft line between them, and to apply the basketry technique of twining to the manufacture of cloth. They also, after abandoning the attempt to grow the paper mulberry and to utilize the bark of the New Zealand lace-bark tree, had to develop a technique for handling the New Zealand flax (*Phormium tenax*), from which all the garments were made, except the raincapes in which *kiekie* (*Freycinetia banksii*) and *toi* (*Cordyline indivisa*) were used.

In preparing the flax the outer surface of the blade was cut across with a shell and either scraped off painstakingly or peeled off with a quick jerk. If the inner surface was scraped very lightly it remained the rich golden color of the woven bag in the collection. For purposes of weaving clothing it was scraped more carefully. After being washed and scraped again and hanked, it needed only a further rubbing between the hands to separate the fibers, to be ready for use as warp material. At this stage it has the peculiar silken sheen so conspicuous in the material of the body of the undecorated cloaks. For the soft inner surface of cloaks, on which ornamental tags and feathers lessened the necessity for a beautiful texture, the flax was washed again and beaten on a flat stone with a stone pounder.

The flax cord was prepared by rolling it on the bare thigh with their right palm, with two movements—one away, the second towards the body. When a two-ply cord was needed, two equal portions were rolled together, but kept separate in the motion away from the body, and twisted together in the return stroke.

Fig. 16. BAG decorated with feathers.

The Maori used no spindle and no suspension beam at the top of their looms such as were used in the looms of American Indians. The place of this beam was taken by the first weft line, called the "ridge pole weft," in which warps of appropriate length had been twined. Only after this line was made did the worker stretch it between the two weaving poles, eighteen inch posts, carved or knobbed at the top, and pointed at the bottom. In the weaving of important garments it was customary to

release the right hand stick and roll the work up at sunset, and it was etiquette to release the stick and make a feint of rolling up the work when a visitor approached.

Each weft line was doubled around the first left hand warp and worked horizontally across and knotted at the right hand side, or turned and knotted a few threads in. Each warp had to be handled separately; there was no shedding device of any sort. The distance of the weft lines from each other varies from 1.6 cm. in the kilt to .59 in the *taniko* borders and there is also variation from wide spacing in the upper part of the garment to closer spacing in the lower part. When feathers or tags were attached it was necessary to make the garment upside down, so that the

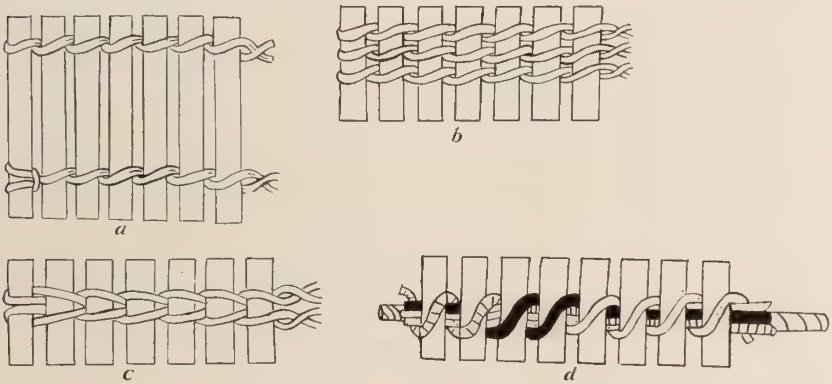


Fig. 17. WEAVING TECHNIQUES. a, Spaced single pair twining. b, Close single pair twining. c, Two pair interlocking weft. d, Wrapped twining used in the *taniko* borders. (After Dr. Buck's analysis.)

suspended tags would not be in the worker's way during the weaving process. Where there were no tags, garments could be made right side up, allowances being made for the attachment of borders, for as the Maori always worked horizontally, it was sometimes necessary to change the position of the garment during its manufacture.

The weft techniques used were four in number: spaced single pair twining (a, Fig. 17); close single pair twining (b, Fig. 17); two pair interlocking weft (c, Fig. 17); and wrapped twining used in the *taniko* borders (d, Fig. 17); *a* was used in kilts, rain capes, and rain cloaks; *b*, in war cloaks to give a close protective fabric, in dogskin cloaks, and single lines were sometimes used as a variation in spaced single pair twist; *c* is a much improved technique originating in the weft rows used in com-

mencing a garment and employed in all finer work; and *d* was used to give the intricate *taniko* border patterns. In *d* the weft cord was composed of several differently colored strands which might be concealed behind the warps or used as the design demanded. A stiffening cord was also used which was carried straight across and not utilized in the design.

In order to fit his garment to the contour of the body, the Maori developed a technique of weaving in either elliptical or wedge-shaped inserts to give the extra width necessary at shoulder and hip.

The simplest form of attachment of tag material is the rain cape (Fig. 18a) with a veritable thatching used to turn the rain. This was effected by using short warp lengths and leaving one end free or by

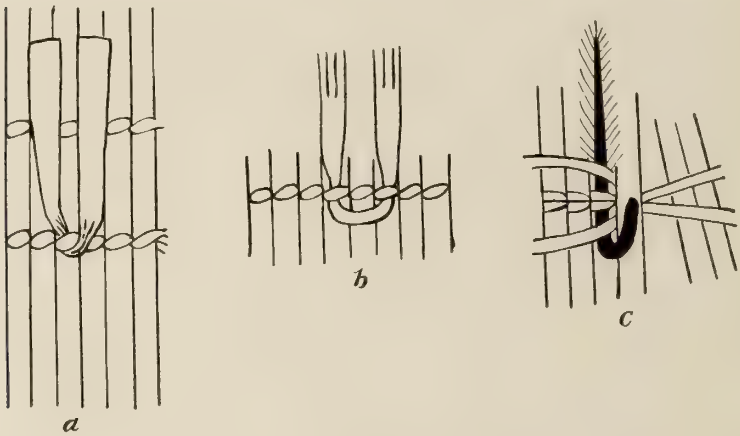


Fig. 18. ATTACHMENT OF TAG MATERIAL. a, Simplest form used in rain capes. b, Elaborate technique used in finer cloaks. c, Attachment of feathers.

adding extra pieces of material and including them under the weft rows. From this utilitarian garment developed the custom of adding ornamental tags of thick cord, or rolled strips of flax. When tags were used in the finer garments, a new technique, that of placing the middle of the tag piece under the weft row, was used (b, Fig. 18). When used as ornaments, tags were spaced farther apart and became purely decorative, taking various forms: loops, spirals, circles, ovals, and twists. When feathers were used, the same technique was employed in fastening them (*c*), the feather being fastened vertically with the tip upward and the bent quill end caught twice in the weft. Tassels for a very much valued type of cloak were made of dogs' hair and strips of dog skin were also used for ornament.

Fig. 19. CLOAK showing taniko border.

The types of Maori clothing can be divided into: the *maro* or small triangle-shaped apron, the simpler ones made of flax fiber or sedge, the more elaborate ornamented with various types of tags; the *piupiu*, kilts or short skirts falling from waist to knees, made of strips of flax scraped at intervals, so that when they were dyed, only the fibrous parts turned black: capes *mai*, *pokeka*, or *pora;* short mantles which only covered one shoulder and reached to the waist, and made of *kiekie* or *toi* as well as flax—occasionally rolled strips like those in the kilts were used; and cloaks (Fig. 19), upon which the whole range of Maori technique of weaving and ornamenting was expended.

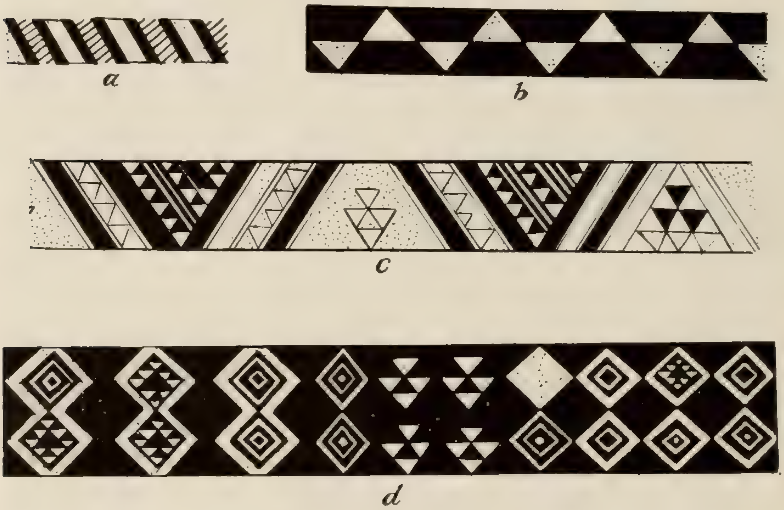


Fig. 20. TANIKO DESIGNS

The student of art will be mainly interested in the *taniko* (Fig. 20) patterns, borders woven in several colors with the elaborate combination of triangles and lozenges. The Maori also wove coarse floor and bed mats of undressed flax and made many types of bags of which there are several good examples in the collection.

While the bulk of the weaving was done by the women, parts of the fine cloaks and especially the *taniko* borders were done by the men. It was to a girl, however, that a ceremonial initiation into the art of weaving was given. A priest, who was a master of both ritual and technique and the young girl, went alone together into the *whare pora*, weaving house. Over a bunch of flax which she held in her hand the priest recited

an incantation to make her holy enough to handle the sacred thread and before fastening it across the weaving frame she had to bite the sacred right-hand stick. She then began to weave, copying some old and beautiful garment spread on the ground before her, while the priest chanted an invocation to make her learn quickly and well. Until her initiation was finished, she was not allowed to eat, to approach cooked food, or communicate with anyone. Her first web was never finished but left as a "pattern piece"; before she could finally leave the weaving house the priest prepared a ceremonial meal which novice and teacher ate together, thus removing her sacredness and freeing her to weave in safety all the rest of her life.

TATTOOING

Like most of the Polynesian peoples, the Maori practised tattooing and brought the art to a higher degree of perfection than any other Polynesians, except possibly the Marquesans. The Museum is fortunate in having the magnificent Robley collection of preserved Maori heads, the finest collection of such heads in the world.

The Maori preserved the heads of their chiefs and also of beloved wives or favorite children, and the heads of their enemies. Of their enemies, only the head of a chief, and beautifully tattooed heads of other warriors were preserved. An untattooed man was left where he fell. During a war these captured heads were exhibited and paraded as encouragement to the warriors, and as a goad to further ferocity. An important element of a peace treaty was the exchange of the heads which had been carefully embalmed during the war. Should a chief destroy the head of an enemy chief it was a sign that peace would never be concluded. Thus the preservation of heads played a double role; it kept alive the memory of the dead, and at the same time preserved the work of the artists in tattoo, of whose skill, expended on perishable human flesh, we have such scanty records in the other islands. In later times, pieces of handsomely decorated thigh skin, such as the piece exhibited, were stripped off and used to cover cartouche boxes.

To preserve the heads, the Maori took out the brain and all the fleshy matter inside the skull, stuffing the cavities with flax. The head was wrapped in leaves and steamed and then exposed to the smoke of a wood fire impregnating the skin with pyroligneous acid which acted as a preservative. All flesh was removed and flax or bark used as packing to restore the face to its original contours. The nose cavity was stuffed with fern root and the lips sewn together, or left so as to show the teeth.

Fig. 21. TATTOOED HUMAN HEADS from the Robley Collection in the American Museum of Natural History. Carved drinking tube.

The skin at the bottom of the skull was drawn together, leaving an opening about the size of the hand.

There were two types of tattooing in New Zealand, the elaborate curvilinear patterns of the northern Maori and the simple straight line tattooing of the southern Maori. Two kinds of instruments were used in the northern group, one a small, toothed, bone adze similar to that used throughout the Polynesian area, the other a sharp single-pointed instrument, used in making the singular deep furrows characteristic of the northern group. The blade of the instrument was made of bone and attached to a wooden handle which contained a forefinger rest and was sometimes decorated. The single-pointed *moko* was like a chisel with

Fig. 22. TATTOOING DESIGNS. a, A forehead design. b, A cheek design.

a whale-bone blade. One end of this instrument was shaped like a flat knife to wipe off the blood. Pigment was made by burning several kinds of wood, or sometimes the vegetable caterpillar, in a small kiln. The soot was collected on a frame of flat sticks and was mixed with dog fat. It was either used in this form or else fed to a dog and the kneaded fæces used. The pigment from the burnt *kauri* gum was sometimes collected on a basket smeared with fat, and kept thus for generations. The pattern was usually sketched on with a mixture of charcoal and water, or with a sharp point. The instrument was either dipped in the pigment or the operator held a little of the pigment between the thumb and forefinger and drew the chisel through it. The blood was wiped away with a piece of flax, a wooden spatula, or the end of the instrument.

Men were tattooed on the face, the upper part of the trunk, and the thigh to the knee. Women were tattooed on the lips, between breast and navel, on the thigh, and on the hands and arms; but more usually they had only a compact design on the lips and chin.

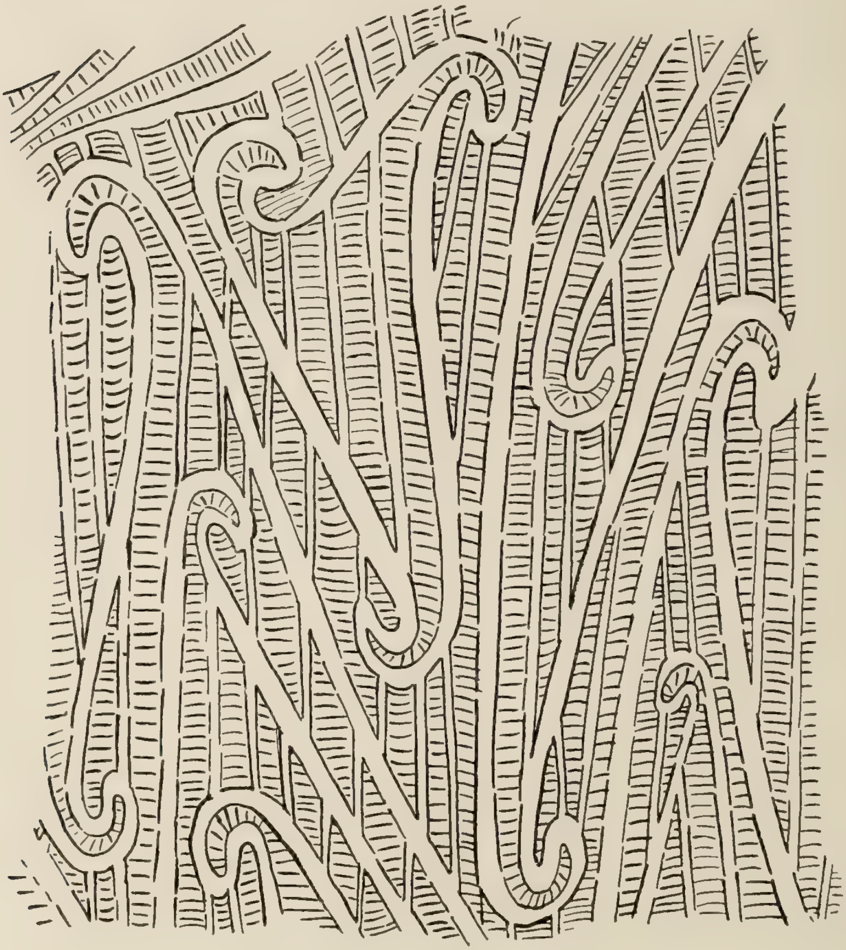


Fig. 23. TATTOOING DESIGN ON THIGH

The professional tattooers were well-paid itinerant individuals. Slaves who knew the art were immediately freed.

The religious aspect was particularly emphasized by the stringent taboos. During the process the whole village was taboo, and the patients

were not allowed to feed themselves with their own hands. To meet the requirements of this taboo, feeding funnels were made and were often elaborately carved like the one exhibited in the case of Maori heads, shown in Fig. 21. At the conclusion of the operation, three ovens were lighted, one for the artificers, one for the gods, one for the newly tattooed and the rest of the people. The priest, by a ceremony of cooking food which was then ceremonially eaten, freed the people from the taboo. A human victim, to obtain which a war party was dispatched, was sacrificed when a chief's daughter had her lips tattooed. Contrary to the usual Polynesian practice, tattooing was done, not at puberty, but after full growth was attained. Women were always tattooed on the lips before marriage. Definite tattoo marks were not used as badges of mourning, but the ceremonial cuts women made on their bodies were filled in with pigment. Heads of dead relatives were sometimes tattooed.

Tattooing was more definitely associated with war than with rank. Slaves taken in childhood were not tattooed and there were particular patterns which a slave could not wear. But many chiefs were not tattooed at all and priests had only a small blotch over one eye. New tattoo marks were sometimes assumed by all the warriors of the tribe before going to war.

The designs used by the southern tribes appear to have been simple series of parallel lines, arranged in groups of three or four, alternately vertical and horizontal. The only curvilinear element was an S-like figure in the middle of the forehead. The designs used by the northern tribes were all curvilinear and elaborately stylized in respect to the sex of the wearer and the part of the body to be decorated. Great emphasis was placed on the conformance of the design to the shape of the chin, the cheek (Fig. 22), etc. The thigh pattern (Fig. 23) and the scroll used on each buttock were invariable; but the smaller units used on the face permitted great individuality of arrangement, although all of these were based on a few curvilinear motifs. It is possible to analyze the designs into seven motifs; lines of dots or strokes, mat or plait work, ladder, chevron, circinate scroll, anchor, and trilateral scroll.

SOURCES

Best, E. The Maori (Memoirs of the Polynesian Society, Volume II, 1925).

The Maori Canoe (Bull. No. 7, Dominion Museum, New Zealand, 1925).

Buck, P. H. The Evolution of Maori Clothing (Memoirs of the Polynesian Society, Vol. VII, New Plymouth, New Zealand, 1926.)

Hamilton, A. The Art Workmanship of the Maori Race. Wellington, 1896.

Robley, H. G. Moko or Maori Tattooing. London, 1896.

Ponnamu—Notes on New Zealand Greenstone. London, 1915.

Roth, H. L. The Maori Mantle. Halifax, England, 1923.

Maori Tatu and Moko (Journal of the Royal Anthropological Institute, Vol. IV, p. 24.)

Skinner, H. D. Evolution in Maori Art. I (Journal of Royal Anthropological Institute, vol. XLVI, p. 184).

Evolution in Maori Art. II, Pendants (Journal of the Royal Anthropological Institute, Vol. XLVI, p. 309.)

The Two-headed Clubs of the Maori (Journal of the Royal Anthropological Institute, Vol. XLVIII, pp. 198–213.)

Tregear, E. The Maori Race. Wanganui, New Zealand, 1904.

DRAMA OF THE MICROSCOPE

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ROY WALDO MINER

Curator of Lower Invertebrates

GUIDE LEAFLET SERIES No. 72

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SECOND EDITION

THE AMERICAN MUSEUM OF NATURAL HISTORY

NEW YORK, 1931

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THE NEW ROTIFER GROUP

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AN ENCHANTED FOREST OF THE MICROSCOPIC WORLD

A detail of the new Rotifer Group in the Darwin Hall of the American Museum, constructed entirely of glass, and faithfully portraying many of the strange plants and animals that normally might be found in one half inch of pond bottom, magnified to more than four feet in diameter

A DRAMA OF THE MICROSCOPE

The Microscopic Life Found in One-Half Inch Pond-Bottom Magnified One Hundred Diameters or, Cubically, One Million Times

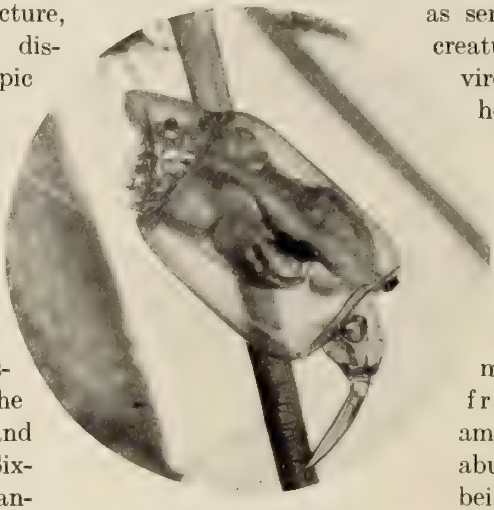
By ROY WALDO MINER
Curator of Lower Invertebrates, American Museum

The new Rotifer Group in the Darwin Hall of the American Museum was designed and directed by Doctor Miner. The field work on which it is based was largely carried on at Mt. Desert Island, Maine, by Doctor Miner in collaboration with Mr. Frank J. Myers, whose intimate knowledge of rotifer anatomy, natural history, collecting methods, and microscopic technique were of inestimable value during the preparation of the group. The field color sketches were prepared by Dr. George H. Childs, under Doctor Miner's direction. The remarkable glass modeling which is the outstanding feature of the exhibit is the work of Herman O. Mueller, of Doctor Miner's staff of artists, and sets a new mark in work of this kind, both as an achievement in skillful preparation of the hundreds of component models, and in the successful assembling into one complex whole of a multitude of fragile parts. The delicate coloring of the models and background is the work of Mr. W. H. Southwick, while those features of the pond bottom constructed in wax were modeled by Mr. Chris E. Olsen.—The Editors.

MORE than three centuries have passed since Zacharias Jansen of Middelburg, in the Netherlands, and his fellow townsman, Johannes Lippershey, produced two little instruments destined to have most far-reaching effects upon human knowledge. Both were contrivances in which crude glass lenses played a most important part. Jansen's invention was the first microscope, and was in use by 1590. Lippershey's was the telescope, which was sold by him in 1609. The following year, Galileo, in Italy, had heard of Lippershey's invention and spent a night considering the optical principles involved. By the next morning, he had reinvented the instrument for himself, and, a little later, adapted it for examining minute objects. Jansen and Lippershey were merely ingenious opticians. Galileo's adaptation of the telescope to astronomical purposes and the remarkable discoveries he made with it have coupled the instrument inseparably with his name, so that he is commonly credited with its invention, and, according to an enthusiastic biographer, with that of the microscope, as well. While all credit is due, therefore, to the two Dutch opticians for originating the telescope and the microscope, it was the genius of Galileo that perceived the significance of the former instrument and by its aid he overthrew for all time the ancient Ptolemaic cosmogony, assiduously fostered by the ecclesiastics of the day, and demonstrated the truth of the essentials of the Copernician theory. From that time on, to all intelligent men, the earth moved around the sun. The world now knew that Jupiter had satellites, that the strange planet, Saturn, existed, that there were spots upn the face of the sun, the observation of which proved its rotation.

While the microscope was not at first used for the study of natural history, by the middle of the Seventeenth Century, a group of keen observers, including Hooke and Grew in England, Malpighi in Italy, and Swammerdam and Leeuwenhoek in Holland, turned its magnifying power upon hitherto invisible details of animal and plant structure, and the last-named discovered the microscopic world of life.

Men had formerly lived in a world bounded by the limits of their unaided eyesight. That which existed beyond was the subject of more or less fantastic surmise. While the mathematicians and astronomers of the Sixteenth Century dimly anticipated something of the truths of the universe outside the range of their visual apparatus, the invention of the telescope and the microscope suddenly furnished glass windows to the practically flat and two-dimensioned room in which mankind had hitherto dwelt. Through the one they now gaze up into the starry heavens to see the planets swinging on their appointed courses around the sun. They penetrate interstellar space and comprehend that the twinkling stars are immense suns of other systems, that outside our universe are other unbelievably distant universes dimly shadowed like luminous cloud patches. Through the other window, the microscope, they gaze down into their own world of life, so enlarged by the magic of refracted light rays, that even the minute cells of animal and plant tissues are disclosed to view, as the fundamental units of living structure. In a drop of pond water, Leeuwenhoek saw myriads of minute living creatures, the existence of which was hitherto unsuspected, because invisible to man's naturally coarse vision. These living beings crowd their watery habitat, hurrying hither and thither on the business of life, as seriously intent as the creatures of our larger environment. Leeuwenhoek thus became the pioneer adventurer in this new world, which interpenetrates our own so intimately, and yet, through the accident of size, is so immeasurably separated from us. He was amazed at the variety and abundance of these tiny beings and his writings betray his confusion of mind. His letters, published from 1673 to his death in 1723, largely written to the Royal Society of London, were filled with accurate but yet miscellaneous descriptions of his observations. They were accompanied by a wealth of drawings, remarkably faithful, considering the time in which he lived and the crudity of his instruments. For his microscopes were mostly simple magnifiers, which he ground and mounted himself. He possessed 247 of these, containing 419 lenses, which apparently gave him magnifications of from 40 to more than 270 diameters. They must have been of fine quality, for the most part, judging from his results.



A SAVAGE ROTIFER

Dicranophorus crouching to spring upon its prey. Lightly balanced on its pointed toes, with body contracted, it awaits an unwary victim

Among the most conspicuous of the microscopic creatures that attracted Leeuwenhoek's attention were the animals since known as rotifers, of which he pub-

A ROTIFER JUNGLE SEEN THROUGH A MICROSCOPE

The new Rotifer Group in Darwin Hall of the American Museum, exquisitely modeled in glass, represents a cubic half inch of pond bottom magnified one hundred diameters, or, cubically, one million times. A spray of the carnivorous water plant *Utricularia vulgaris* spreads its bladder-shaped animal traps diagonally across the field of view, to snare the microscopic rotifers and other tiny creatures which make up its food

lished descriptions in 1703. A contemporary investigator, the Rev. John Harris, antedated him by seven years in making the first published, but rather vague, description of an undoubted rotifer. Thus, these remarkable inhabitants of the minute world, first recorded in 1696, have been known to microscopists for 230 years. Yet it is quite likely that by far the greater majority of educated persons today have never heard of them, and at the first mention of their name, would immediately ask "What is a rotifer anyhow?

The new exhibit in the Darwin Hall of the American Museum is intended to answer this question. Rotifers are unknown, simply because of their small size. The new Rotifer Group enlarges a cubic half-inch of their watery habitat, to one hundred diameters, or, cubically, one million times, so that it occupies a space measuring fifty inches, or more than four feet across. The front of the exhibit is constructed to represent a huge magnifying glass, through which the visitor peers into a jungle of water plants peopled by hundreds of tiny animal forms. In their natural size, these plants would cross and recross an area about the size of one's thumb-nail. Here, they are so greatly enlarged that they appear to tower above the observer's head, and their great size gives them a strange and unfamiliar appearance. These and all the other remarkable and complex features of this group have been skillfully modeled in glass to represent the life of a minute area exactly as it appears through a microscope. To the right, a cluster of water thyme (*Philotria canadensis*) rises with slender, pointed leaves and graceful translucent green stems. To the left, and arching also over from the right, criss-cross tangles of *Spirogyra* interweave their slender, tubular strands. When seen in natural size, this plant appears to consist of close tangles of slender silken threads of green, which gather in great masses in still water, and is familiar to us all under the name of "pond scum." It is supposed by many people to render the water noxious. The opposite, however, is true, as the green color of the scum is due to the abundant chlorophyll, which, under the action of sunlight, breaks up the harmful carbon dioxide gas of stagnant waters, utilizing the carbon for food, and releases free oxygen, thus rendering the water purer. In the magnified representation of *Spirogyra,* shown in the group, the strands are seen to be formed of cylindrical cells set end to end, and the green chlorophyll is gathered into spiral bundles (chromatophores), giving the strands of the plant a spirally striped appearance. Hence, the name, *Spirogyra,* is quite appropriate. When two strands of *Spiro-*

A ROTIFER CLIMBING UP A PLANT STEM

With swimming discs folded in and concealed, *Rotaria macrura* hunts for small organisms along a *Spirogyra* stem, advancing like an "inch worm" by alternately arching and extending its body

FLOWER-LIKE ROTIFERS SETTLED IN A NOOK AMONG THE WATER PLANTS

A colony of tube-building rotifers (*Floscularia ringens*) has built a branching cluster of trumpet-shaped "houses" on the edge of a dead, skeletonized leaf. In the center is the transparent, double dwelling of a pair of graceful, comb-armed rotifers (*Stephanoceros fimbriatus*), which are really ingeniously contrived animal traps of voracious habit. In the foreground, the large and unusually beautiful *Octotrocha speciosa* peer out of their jelly-like habitation

gyra come in contact, the cells which chance to be closest send out hollow projections to fuse with those of the opposite strand and connect the cells in pairs. The chromatophore of one cell of a pair thus united, then passes out of it through the connecting canal into the other cell and unites with the substance of its chromatophore, forming an oval body, which, after union of the cell nuclei, becomes a spore. This is released into the water and eventually starts the growth of a new plant.

Diagonally across the center of the group is seen the most remarkable plant of all. This is the bladderwort, *Utricularia vulgaris*. Its stem is slightly zigzag, and, through its translucent walls may be seen the green vascular bundles of the internal structure. Along the stem, at intervals, are slender, branching, spine-like leaves, which, in real life, are very delicate and flexible. From the stem of each of these grows a curious bladder, also called a utricle. These bladders give the name, bladderwort, to the species. From the word, utricle, is derived the scientific name, *Utricularia*. These utricles are actually animal traps. They are about the size of a pin-head, but are shown here, modelled in glass, about three or four inches in diameter. The tiny animals, with which our microscopic world is swarming, are captured by these traps and, as they die and decay, are absorbed by the plant cells for food.

THE TIGER SPRINGS

The *Dicranophorus* darts upon its victim with open, pincer-like jaws (seen at the right), and relaxed and now slender body. This is the same species of rotifer as the one shown on page 4

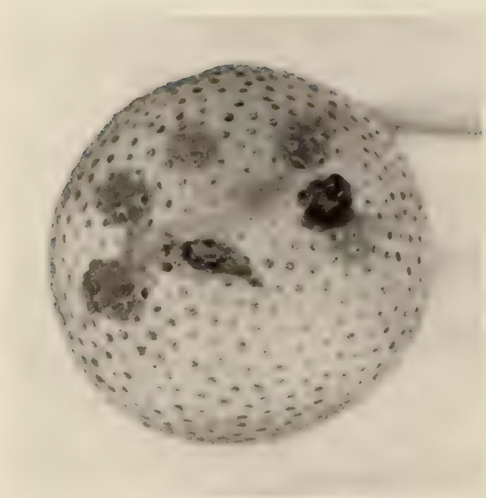
This reminds us of the terrestrial pitcher plants, which capture and digest insects on land. Growing upon the main stem of the bladderwort, we see hosts of minute plants, the unicellular algæ. These are of many varied species, and are so crowded together that they appear like a fine green or brown fluff when seen by the naked eye.

We have examined the vegetation of our microscopic jungle. Let us now become acquainted with its inhabitants, the minute creatures that swim or prowl through its tangled growths or build crystal palaces, in which they dwell upon its branches.

As above mentioned, the most conspicuous of these are the rotifers. The typical rotifer is a somewhat top-shaped animal, that is to say, its body tapers from a relatively large, often flattened head, to a more or less pointed foot, usually furnished with two, likewise pointed, "toes." An excellent description with illustrations was given in a recent number of NATURAL HISTORY by Frank J. Myers, in an article entitled "What is a Rotifer?" (May-June, 1925, page 211.) The head has a crown of cilia, i.e., minute moving hair-like structures. The arrangement of this "corona" varies in different species. In some cases, as in the common rotifer (*Rotaria macrura*), these cilia are arranged in a double row around two circular discs, which are literally borne on the shoulders of the animal, just back of the

A WATER PLANT THAT TRAPS AND DEVOURS MICROSCOPIC ANIMALS

A detail of the Rotifer Group showing a single "utricle" of the bladderwort (*Utricularia vulgaris*). This, in the living plant, is about the size of the head of a pin. The trap-door is seen at its lower right margin and a captured rotifer is visible within. A spherical, floating colony of rotifers which cling together by their toes (*Conochilus hippocrepis*) is seen at the right. The stem of the bladderwort is covered with tiny fresh-water algæ, and a crescent-shaped desmid (*Closterium*) shows at the left



A ROTIFER WHICH LIVES INSIDE A COLONY OF PROTOZOA

The spherical colony of the protozoan, *Volvox*, is penetrated by the rotifer *Ascomorpha*, which thereafter lives and feeds inside

mouth-opening and on either side. The cilia lash the water, not indiscriminately, but one after the other in ordered succession. This vibrating movement is so rapid that a wave of motion passes around the discs, giving the appearance of a rotating wheel. Some of the early observers supposed that this was actually the case, and so gave the name rotifers or "wheel bearers" to the animals. They thought that, at last, the principle of the wheel had been discovered in nature, but, with closer observation, it was soon found that this was an optical illusion, and that man still preserves intact as his own invention one of the few mechanical principles not anticipated by nature, namely, that of the wheel rotating upon an independent axis. The rotifer's vibrating coronal circlet of cilia creates a whirlpool in the water, which gathers in still more minute animals, diatoms, and other microscopic particles to be swept down into the vortex where the wide-open mouth is situated. The food stream then passes into a capacious pharynx, to be seized upon by a curious apparatus, peculiar to rotifers, known as the mastax. This is really a set of jaws located in the throat, which differ characteristically in the various species, so that they are used by students of rotifers as a means of identification. In many species, they take the form of toothed forceps that tear the food apart. In others, they act as a grinding mill, and, in still others, as a suction pump. Rotifers of the first sort are active and sometimes prey upon animals of their size or larger. In this case, the rotifer springs upon its prey, suddenly shooting out nipper-like jaws until they project from its mouth, thus enabling it to seize the captive. An example of this is *Dicranophorus forcipatus* (shown on page 8). The second kind, like *Rotaria macrura,* described above, feeds upon very small forms, while those that have suction jaws are herbivorous, feeding upon the contents of plant-cells. For example, *Monommata longiseta* crawls up the filament of *Spirogyra*, cutting a neat round hole in each cell with the tips of its jaws. Then it uses its pumping apparatus to empty by suction the entire

A ROTIFER WITH STRANGE SWIMMING ORGANS

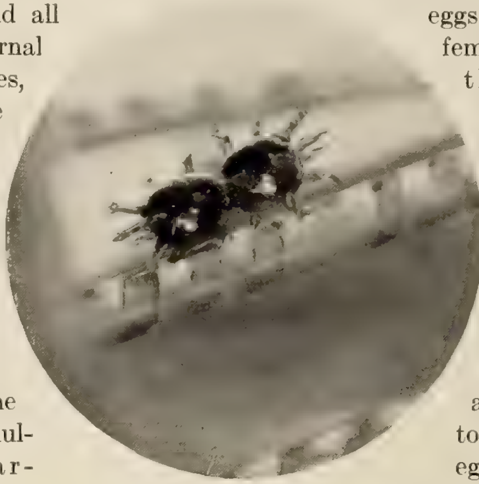
Notommata copeus extends earlike flaps from its head to use in swimming. They are fringed with moving hairs which draw the animal through the water

A PROTOZOAN COLONY OF BELL-ANIMALCULES (*VORTICELLA CAMPANULA*)

Each individual is anchored by a delicate thread of protoplasm which contracts spirally when the owner is disturbed. Highly magnified strands of pond scum (*Spirogyra*) are conspicuous, spiral chlorophyll structures showing through the transparent, tubular walls. Two strands are forming spores, being connected by ladder-like rungs in the process

plant cell of its endochrome. It then proceeds to the next cell to repeat the process.

After passing the mastax, the food reaches the large stomach, which is the most conspicuous organ in the rotifer's body. In the group, it is easy to see this organ and all the rest of the internal anatomy of each species, as the animals are clearly transparent. The stomach has a comparatively thick wall composed of a limited number of large cells which are clearly visible in the larger species and give the organ a somewhat mulberry-like appearance. Here, the food is digested, the residue passing out through the short and straight intestine. One urn-shaped species (*Asplanchnopus multiceps*) has a well-developed mouth and pharynx, as well as a large stomach, but there is no intestine present, the indigestible residue of the food being regurgitated through the mouth.



A MICROSCOPIC WATER PLANT

Xanthidium armatum is composed of two connected cells armed with spines, which enable it to cling to plant stems

All female rotifers have an ovary situated in front of the base of the stomach. When the eggs are developing, this organ may be so distended as practically to fill the body cavity. The eggs are laid in the water in most cases. Certain species, however, hatch them in the body cavity, the young remaining for a time within the mother's body. Males are very few, compared with the number of females, and are of much smaller size. They have a reproductive apparatus, but no mouth or stomach. They are therefore merely sexual machines which swim about for a few hours before perishing. During their brief career, some of them justify their existence by pairing with the females. The rest just die. The fertilized eggs last over the winter and hatch out the following spring to give rise to females. These produce unfertilized eggs which also hatch out females. Thus, during the summer, brood after brood of females are produced, until cold weather sets in during the fall, when male-producing eggs of smaller size are hatched out, making it possible for another sexual mating to give rise to winter eggs, as before.

Rotifers have a nerve ganglion, or "brain," in the head region, in close connection with which one or more red eyespots occur. A system of nerves connects the brain with various parts of the body. They also have paired "kidneys" and a simple muscular system. In short, they are remarkably complex creatures for their small size, and are in sharp contrast to the single-celled protozoa, associated with them in their microscopic environment, which, in some cases exceed them in size.

Thirty-one species of rotifers are shown in the group. This is not unusual in a normal prosperous community found within a cubic half-inch of pond-bottom, under the environmental circumstances represented in the Rotifer Group. A few of the more interesting species will be mentioned.

One of the largest of the rotifers may be seen crawling up a *Spirogyra* filament toward the left of the group. This is

A VISTA THROUGH A TANGLE OF POND SCUM (*SPIROGYRA*)

The spiral chlorophyll of *Spirogyra* is clearly visible. A large rotifer (*Notommata copeus*) is crawling up a strand, systematically perforating it, cell by cell, to pump out the chlorophyll for food. A utricle of the bladderwort is capturing a harlequin fly larva, which is struggling to escape. At the lower left an urn rotifer (*Asplanchnopus multiceps*) is seen, with its internal structure showing plainly through its transparent body

Notommata copeus. It has the habit of perforating the *Spirogyra* cells and pumping out the endochrome, like *Monommata longiseta*, mentioned above.

At about the center of the group, another *Notommata copeus* is seen swimming. It has a pair of "ear-lappets" extending on either side of its head. These are covered with moving cilia, the rhythmic vibrations of which propel the animal through the water. When it settles on a plant stem to feed, the lappets are drawn in. Just below it is a spherical colony of beautiful rotifers (*Conochilus hippocrepis*) consisting of about twenty-five individuals clinging together by their toes, while the combined motion of their wreaths of cilia causes the whole colony to rotate through the water. Close below the latter, a savage *Dicranophorus* is crouched with its toes resting against a branch of the bladderwort, in readiness to spring upon the next unwary creature that swims by. The utricle near it has apparently forestalled the *Dicranophorus*, for, through the bladder wall, a captured rotifer is dimly seen, vainly trying to find a way out.

Farther down the spray of the bladderwort, an insect larva (that of the harlequin fly, *Chironomus plumosus*) has just been caught by a utricle, and is struggling to escape. The more it struggles, the farther in it goes, for the utricle is lined with glandular hairs pointing inward. Thus, only the muscle contractions in an inward direction are effective. Soon the creature will slip wholly within, and will coil up like its fellow in the bladder farther up the stem, finally to be absorbed by this strange carnivorous plant. How is it possible for a utricle to induce a rotifer or other unsuspecting water animal to come and be caught? By looking at the utricle depicted on page 9, it will be seen that there is a trap-door on the lower free corner of the bladder, from the edge of which project long, branched spines. Rotifers and other small creatures delight to browse among these spines, for small forms of life often adhere to them. In the course of their feeding, they may chance to come in contact with the trap-door. The shorter spines on the upper edge of the door hinder them from easily moving away, and meanwhile the slippery, glandular hairs which cover the surface of the trap cause the victim to slide toward the depression at the upper edge. Here the trap-door is very thin and flexible with a free edge gently held under a curving lip forming that part of the door-frame. As soon as the creature touches this flexible edge, it suddenly gives way and the unhappy explorer drops through the crevice, which immediately closes. The bladder does not digest the rotifer, for no digestive ferment is secreted, as in the case of terrestrial pitcher plants. The animal gradually dies, the fluid products of decay being absorbed by the cell-lining of the utricle, as food for the plant. Water-fleas and protozoa are also captured in this way.

Various species of protozoa are shown in the group. Down at the left, clinging to the base of the bladderwort stem, is a colony of beautiful bell-animalcules (*Vorticella campanula*). These are animals consisting of a single cell each. Superficially they remind one of rotifers, for the bell-shaped body is crowned by a circlet of cilia, but the internal organization is that of a protozoan, with a nucleus and contractile vacuoles. Each individual is anchored to the plant by means of a long, slender filament of protoplasm, containing a contractile thread of denser protoplasm. If the animal is touched or otherwise disturbed, the thread contracts, drawing the stem suddenly down to a close spiral, while the bell-shaped body and its ciliated disc contract into a ball. Soon the thread relaxes and the stem slowly lengthens, while the ciliated bell gradually expands and starts beating the water as merrily as ever.

A TUBE-BUILDING ROTIFER BUILDS ITS CHIMNEY-LIKE DWELLING
Floscularia ringens extends its pansy-like head from the top of its tube and models tiny, spherical bricks of brown mucus with the aid of the finger-shaped projection just back of its head. When finished, these are neatly cemented to the tube margin. The rotifer's home is thus built up like a tiny chimney of the most delicate masonry, resembling fine mosaic

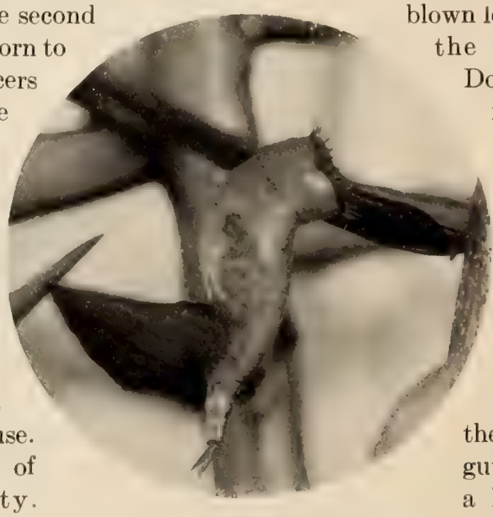
A little to the right of the center is a floating transparent ball, covered with hundreds of tiny green dots, enclosing a number of small dark green spheres. This is a protozoan colony (*Volvox*), often found in fresh water during the spring. The living colony is about half the size of a pin-head, and is very beautiful as it rotates slowly through the water. Each green dot is an individual protozoan, while the small green spheres within are developing *Volvox* embryos. Strange to say, a species of rotifer (*Ascomorpha volvocicola*) lives within the colony, and hatches its eggs there. The young grow and feed within the colony, possibly on the developing *Volvox* embryos, eventually making their escape, only to bore their way into other colonies of *Volvox*.

Perhaps the most beautiful of the rotifers are the flower-like stationary species. A good example is the tube-building rotifer, *Floscularia ringens*. The ciliary wreath of this fairy-like creature extends its petal-shaped lobes, causing it somewhat to resemble a pansy, around the rim of which the extremely delicate cilia vibrate in succession, like a transparent halo of motion. This animal builds a trumpet-shaped chimney to dwell in of tiny spherical bricks of brown mucus, secreted from glands of its body. It spins them into balls one at a time, by means of a hairy, spinning-projection upon its shoulder, and then, with a bob of its head, adds them to the upper rim of the chimney, which thus grows higher and higher. When the young are hatched, they make

their way out of the tube, and settle down on the outside of the parental mansion, to construct their own homes as additions to it. Soon, quite a branching cluster of these chimneys will be built up. Such a cluster may be seen on the edge of the dead leaf at the bottom of the group.

In the lower right-hand corner, near the branching chimneys of *Floscularia*, are magnificent clusters of two other stationary species. One of these, *Stephanoceros fimbriatus*, has built a double chimney of transparent gelatinous material, and shows one individual retired into its house, while the other extends its graceful head with five curving, fern-like arms out into the water. Fairy-like as this creature may appear, it is a most insatiable animal-trap, for its arms form a net to entangle swimming rotifers or protozoa. These settle down into a funnel-shaped vestibule from the bottom of which a hollow whip extends into a second chamber below. When the victims in the funnel touch the base of the whip, they are suddenly *snapped through its hollow lash* into the second room. Here they are torn to pieces by toothed pincers and conveyed to the stomach. So the fairy, after all, is a most voracious Gorgon!

In front of this creature, may be seen a colony of flower-like rotifers, living clustered in a roomy gelatinous house. This is a species of remarkable beauty. Its scientific name is *Octotrocha speciosa*. It was first discovered in China. Then some years ago, it was found in a pond on Long Island. Later on, Frank J. Myers discovered it abundantly in southern New Jersey, and, within the last few years, both Mr. Myers and the writer found it in ponds on Mount Desert Island. For the most part, it occurs in association with dead oak leaves, but, in the latter locality, it was abundant on the water-plant, *Nitella*. How could such a species be of such sporadic and yet wide-spread occurrence? The most probable answer is doubtless the clue to the wide distribution of many rotifers. When pools, in which rotifers occur, dry up, the animals may die or, in case of many individuals, they may go into what is known as "resting stage." The rotifer telescopes into a contracted condition, and stops, with plugs of hardened mucus, any openings through which its small modicum of moisture might evaporate. In such a state, it will resist drying up. Yet, being of the size of a mote, it is easily caught by wind currents and blown long distances through the upper atmosphere. Doubtless, millions of rotifers, as well as their winter eggs, are sown all over the world by the winds, and, when dropped in favorable localities, they dissolve out, come to life, and prosper once more. It is a fact that the dust from a dry rain gutter, on the eaves of a house, will be found prolific in bdelloid rotifers, when placed in a dish of water.



A TYPICAL ROTIFER

Cyrtonia tuba is a top-shaped creature crowned with a wheel-like wreath of cilia

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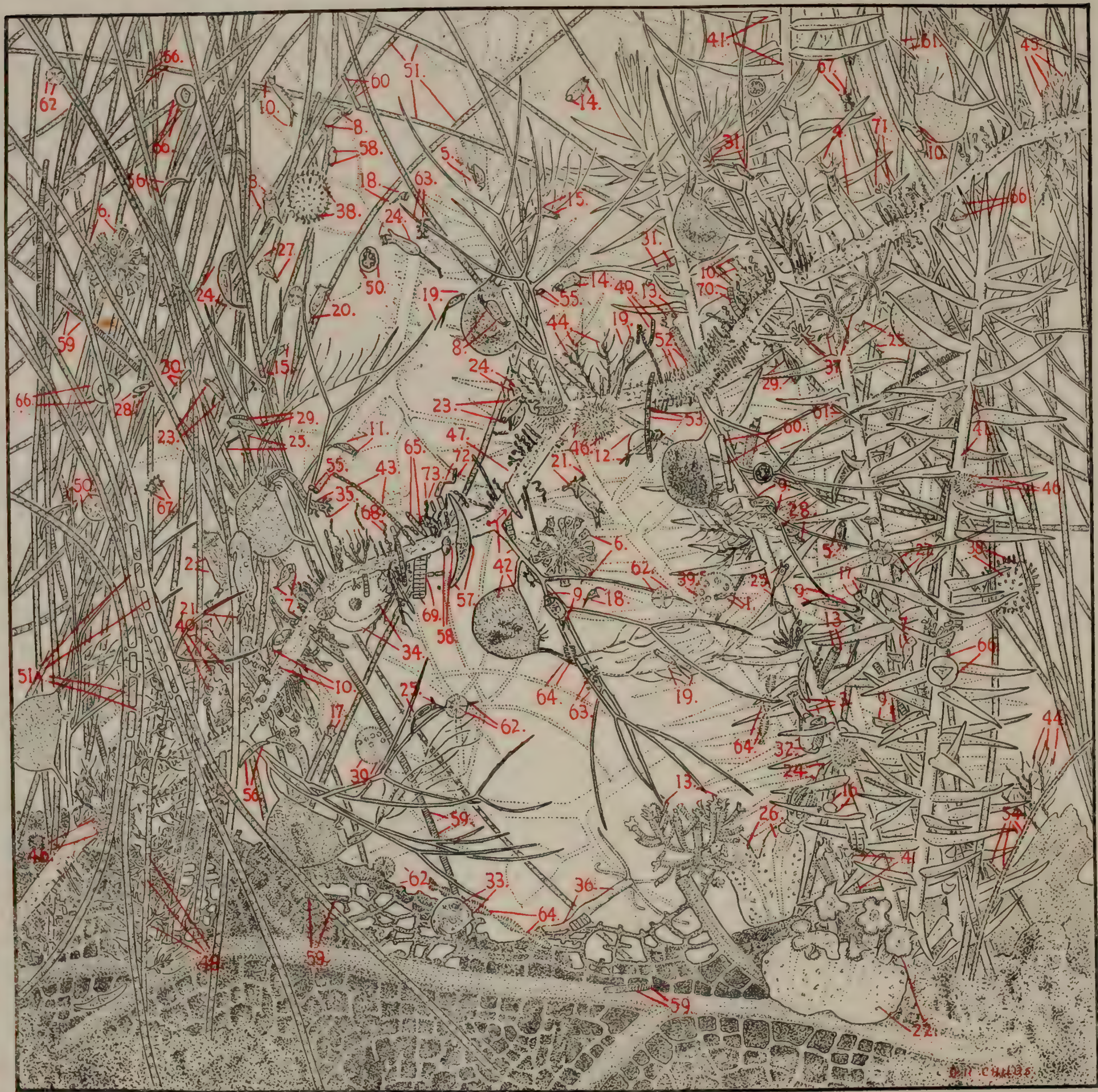

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POTTERY OF THE SOUTHWESTERN INDIANS

BY PLINY EARLE GODDARD

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INTRODUCTION

The pottery of America differs in two important respects from that of the Old World. For several thousand years the potter's wheel has been used in the Old World and the ware has been covered with a vitreous glaze. In America the potter's wheel was unknown in pre-Columbian times; glaze was sparingly used and not over the entire surface of the vessel. When the potter's wheel is employed the centrifugal force produced by its rapid revolving throws the paste outward against the bare hand or some implement and the vessel of necessity takes on a circular shape. The vertical outline is controlled by moving the resisting hand in toward the center or away from it as may be desired. In America, where the Indians do not use the wheel, vessels are sometimes shaped in a mould or modeled free-hand. Usually, however, they are built up by applying cylinders or ropes of clay, round by round, or in a long spiral. These successive rounds of clay are made to adhere by pressure exerted with the fingers.

From the Southwest a great abundance of pottery vessels has been secured. Some of these are of recent manufacture, made by the Indians now inhabiting the Pueblo villages. A much greater number has been recovered from the ancient ruined Pueblo buildings and from the nearby burying grounds.

METHODS OF MAKING

The methods employed in making pottery in ancient times can only be surmised, but for the modern peoples we have excellent detailed information. The following account is based upon the work of Dr. Carl Guthe.

The women go to the clay pits from which the material has been secured for generations and bring back a supply in a shawl or some other container which they can carry on their backs. The clay is first very carefully sifted and hand picked to remove all pebbles and other extraneous matter. To the clay is added a considerable amount of tempering material, sand, finely pulverized lava, or ground fragments of discarded pottery. When the materials have been thoroughly mixed, water is added, and the mass kneaded with the hands. The amount of tempering

material is judged by the potter without resorting to measurement. There must be sufficient to prevent the cracking of the vessel when it is sun-dried and not enough to cause the vessel to fall apart.

When the material has been prepared, the vessel is begun by molding the bottom portion with the hands. This is placed on a shallow bowl-like piece of pottery to support the vessel and allow it to be moved about without direct handling. To this molded bottom is applied round after round of the paste rolled into cylinders or ropes. It is usually necessary to allow the material to dry after the addition of each three or four rounds of the moist clay. While one vessel is drying another may be worked upon. The vessel is given its approximate final shape as it is built up, but the modeling is completed by rubbing the inside with a piece of gourd shell, while the hand is held on the outside of the vessel directly opposite to control the amount of pressure exerted. The exterior of the vessel is also rubbed down and all traces of the method of building up with cylinders of clay are obliterated. The modeled vessel is then set aside to dry either in the sun or in the house oven with a slow fire.

When the vessel is sufficiently hardened by the slow drying it is scraped to produce an even surface and polished or smoothed. The next step is the application of a slip on the surface of the vessel to be decorated. The material employed is a fine clay, either white or red, of which a saturated solution is made in water. This is applied to the vessel with a small mop in five or six coats, each of which is allowed to dry before the next is applied. This slip is polished with a smooth, water worn pebble. The designs are drawn in free-hand with a brush made of a strip of yucca leaf, the end of which is frayed. The paints employed are black or some shade of red. The latter material is a mineral and the color is no doubt due to the presence of some form of iron. Black paint, however, is of vegetable origin. A syrup is made from bee-balm, a thick-stemmed herbaceous plant which is boiled in water for several hours before the syrup is of a sufficiently dense consistency. It is allowed to ripen for several months after being prepared and is then ground in water and applied to the vessel. The black color is no doubt due to the carbonization of this syrup, the fire not being sufficiently hot to consume the carbon.

When a number of vessels are ready for firing the oven is prepared. A fire is built on the ground where the firing is to take place. After the fire has burned down a grate-work is put in place a few inches above the surface of the ground. On this the vessels are arranged, bottom side up, so that they will rest securely. Around these vessels are placed slabs of manure from the corrals. Sheep manure is preferred, horse or cow

manure may be employed. The material must be thoroughly dried so as to burn evenly. Kindlings are placed under the grate and set on fire. The woman watches her ware closely, noting the color, and when that is just right withdraws the fuel, removes the vessels, and places them where they will cool.

METHODS OF ORNAMENTING

The visual effect of a pottery vessel depends first upon its shape and second upon the character and treatment of its surface.

The forms of the vessels in the Southwest vary somewhat with the locality, but a classification into several prevailing types may be useful. The following are usually recognized. Bowls are vessels with wide mouths and sloping sides that are not straight; usually the walls of the bowl flare outward, but in some cases they recurve toward the top, forming a hemisphere or somewhat more than that. Ollas have narrow mouths and curved sides. In some cases vessels are provided with vertical lips for holding covers in place. Cylindrical jars occur with straight or fairly straight walls and therefore with mouths of medium width, the vessels being taller than they are wide. Pitchers have a constricted top and a vertically placed single handle. Ladles and spoons both occur, the former having hemispherical bowls which may have been derived from the use of gourds. Besides these recognized forms, there are many curiously shaped vessels, including human effigies.

The character of the rims of the vessels is frequently employed in the classification of pottery objects, particularly where only sherds are available. In some cases the rims are straight, in others they are curved inward or outward; the edges may be either flat, rounded, or sharp.

The second important feature giving a definite appearance to pottery vessels is the treatment of the surface. This may be merely smoothed down and left plain or it may be ornamented. The ornamentation may be produced by making the surface uneven so as to cause variation in light and shade. This is accomplished by several methods. One of widespread use is to indent the surface of the vessel, while it is still soft, with a pointed instrument, by the application of a carved paddle, or by rolling an incised disk over the surface, transferring the designs on the paddle or disk to the pottery. A second method is the application of pellets or strips of clay to the surface of the vessel, to which they are made to adhere. In the Southwest these methods are but sparingly used. Lastly the surface may be made to produce light and shade by leaving the successive rounds of clay unsmoothed, with the prints of the finger or implement used in pressing the rounds together left in view.

Pottery of this type is called corrugated and is found generally over the Southwest but is not known in other regions of North America.

The surface of vessels may also be decorated by the use of pigments. Ordinarily the vessel is prepared for painting by smoothing the surface and by applying a slip to produce a uniform background of the desired shade. The designs are then painted in free-hand and become permanent after the vessels are fired.

Southwestern pottery should be regarded from two points of view. The first is historical, tracing the development of the art of making and decorating pottery from their beginnings to the present; and second, the local variations of pottery styles both in ancient and modern times.

ORIGIN AND DEVELOPMENT OF POTTERY

The first people known in the Southwest made no pottery. They were highly skilled in textile art, which is shown by the baskets and woven bags found in their graves. Because of this textile skill they are known as Basket Makers. Following them were a people, perhaps the descendants of the Basket Makers, who mixed clay with strands of bark or cornhusks and molded thick-walled vessels. Many of these were molded in baskets, as can be seen from impressions left on their exteriors. These crude vessels were sun-dried but not fired. The firing would have consumed the vegetable binding material. The people who made this unfired pottery have been assigned to the period known as Basket Maker III, in the Southwestern chronological scale. At the close of this period and during the succeeding one (Pueblo I) tempered or true pottery which was properly fired was made.

Up to this time vertical walled stone houses were not built. When these houses were first constructed the units were so small that they accommodated only one or at most a few families. Somewhat late in the pre-Spanish period the people gathered together in large villages, living in great communal houses. These builders of the straight-walled compound houses are known as Pueblo dwellers. From the beginning until the Spanish period they made two prevailing styles of decorated ware, one in which the surface was left uneven or intentionally made so, producing light and shade; and the other decorated with designs painted on a white or red slip.

PREHISTORIC POTTERY

CORRUGATED

Manipulation of the pottery-making technique, in order to produce ornamentation, may be observed in early examples of fired wares (Basket Maker III). By leaving unsmoothed at the rim, the last few coils of clay used in building up the vessels, broad decorative bands with plain

surfaces were produced. Later, the entire outer surface of the vessels was allowed to remain unsmoothed, showing distinctly each round of the spirally applied rope of clay as well as the finger marks where pressure was exerted to make the successive rounds adhere to each other. Decoration was achieved by treating successive rounds differently, producing a banded effect, and by applying the fingers with some regard for spacing, so that designs were produced. Pottery of this sort is known as corrugated. In most localities these coils of clay are of some width, about five or six to the inch. On the headwaters of the Gila River were a people who specialized in corrugated pottery. Some of their wares have twelve coils to the inch. Not only are these coils very fine but very evenly and regularly executed. These unpainted wares were used largely for cooking. Painted decorations on vessels placed over the fire would soon be obscured by the smoke. The surface of sun-dried vessels before they are burned was sometimes highly polished by smoothing with a stone. If the fire was smothered just before the firing of these vessels was completed, the ware came out a lustrous black. The Santa Clara Indians at the present time make use of this process and the interiors of some of the Tularosa prehistoric bowls have such a finish.

PAINTED WARE

Vessels decorated with painted designs are in most cases first given a slip. The surface of the sun-dried vessels is scraped and well smoothed. The slip consists of a solution of clay in water and the color depends upon its composition. White was most commonly employed in prehistoric times, but vessels with a red slip are distributed over the entire Southwest.

The painting on these prehistoric vessels is chiefly in black. The designs fall into two main classes, depending upon whether the lines are straight and form angles; or curved, frequently making spirals. The spaces which compose the designs may be in solid black or in hatch work, the two being often combined on the same vessel for purposes of contrast. With the exception of one region—that of the Mimbres Valley—the decorations are usually not realistic nor the result of conventionalization, but geometric. Pieces with drawings of animals and men, poorly executed and ludicrous in aspect are rarely found in other regions. The designs generally are applied to the vessels in encircling bands but sometimes in panels. The bands may consist of lines of varying width, or of one or more simple motifs repeated many times. In both the angular and curved designs interlocking is frequently employed. Some of the most characteristic design elements are shown in the illustrations.

LOCAL VARIETIES

The following are the main regions in which distinctive pottery types are found:

Mesa Verde in Colorado and northeastern New Mexico; Chaco Cañon, south of the Mesa Verde region; and Kayenta in north central Arizona, are within the drainage of the San Juan River. On the headwaters of the Gila River, chiefly in the drainage of the San Francisco River, one of its main tributaries, a very special style of ceramics was made. Southward, in the Mimbres Valley, beautiful black-on-white pottery was decorated with many realistic and conventionalized life forms. All these regions were deserted and uninhabited when the Spaniards arrived in the Southwest in 1540. Three important regions in the Southwest have been continuously occupied until the present time—the upper valley of the Rio Grande in New Mexico, the headwaters of the Little Colorado where the Zuñi now live, and the Hopi mesas in Arizona, in all of which there are easily distinguishable styles of pottery decoration. Some of the most striking characteristics for each region will now be mentioned.

The pottery of Mesa Verde may be distinguished by the rim formed by the continuation of the sides of the vessel without a definite inward or outward flare. The full thickness of the walls is maintained and the edge of the rim is flat. The slip is usually a grayish pearly white and the decorations are generally in bands of repeated designs, the key motif prevailing. These bands are bordered by lines of varying width, symmetrically placed above and below. Designs in hatching, are bordered by lines of the same width as those employed in the body. The flat topped rim usually has a row of dots.

The Chaco Cañon ware has a straight rim, rounded or sharp at the edges. The slip is very white and the figures are hatched in fine lines, somewhat wavy, and enclosed by much heavier lines. Frequently narrow lines are bordered with rows of dots.

The Kayenta ware of Kietsiel and Betatakin has a white slip nearly covered with black paint so that in some cases at least the white appears to form the designs. The bands have interlocking keys, frets, and double spirals. Designs are often made by cross hatching of considerable fineness resembling mosquito netting.

The Tularosa pottery on the upper Gila is noted principally for its modeling. One prevailing type consists of vessels which are molded to represent birds. They have vertical strap handles almost invariably terminating in modeled heads. The designs, which generally interlock, are made with solid black and hatching, nicely contrasted.

Not far south of the Tularosa region in the valley of the Mimbres a special style of black-on-white ware developed. Here are found bowls in complicated and very beautifully executed geometric designs. Solid black and hatch work are combined and often cover much of the surface of the vessel. The most astonishing characteristics are the realistic or slightly conventionalized animal figures. These are not only beautifully drawn but very interestingly spaced, often in opposed pairs. Frequently figures of this sort are blocked out in black within a delimited white field.

The four regions mentioned above were not occupied by pueblo-dwelling people at the arrival of the Spaniards and were probably deserted several centuries before that time. There remain to be discussed three districts which were occupied by villages when Coronado's expedition reached the Southwest in 1540. Two of these, Zuñi and Hopi, lie in the drainage of the Little Colorado River. Zuñi is situated in New Mexico, about forty miles south of the town of Gallup, near the headwaters of the Little Colorado, and the Hopi mesas are in Arizona, a considerable distance northwest of Zuñi. Between these still inhabited towns are many ruins of villages deserted before the Spanish occupancy of the country. All along the Little Colorado the earlier ruins yield abundant sherds of corrugated, black-on-white, and black-on-red pottery of the general character described above. At a later date the black-on-white ware was displaced by a more general use of black-on-red. In the Zuñi region a black glaze came to be used in place of black paint. The color of this glaze is not constant, varying toward green or purple. There also occurs along the Little Colorado, dating from prehistoric and early historic times, a ware with a buff or yellowish paste decorated in black, brown, and red. The designs on these vessels have a larger proportion of life forms and of representative or conventionalized decorations than are found in other parts of the Southwest. The most striking examples of this pottery are found at the two former Hopi villages, Awatobi and Sikyatki, which were abandoned in 1680.

The Rio Grande region in the northeastern portion of the Southwest shows a continuous record of pottery development from the early period of small family houses when the prevailing ware was corrugated and black-on-white, down to the present day when the potters of San Ildefonso are making wares for sale to tourists in quite new styles. The history of pottery development in this region has been recovered by the work of N. C. Nelson of the American Museum of Natural History and of Dr. A. V. Kidder of Phillips Academy, Andover, Massachusetts. Mr. Nelson worked intensively in the Galisteo Valley and by making sections of a rubbish heap brought the record up to 1680, when the Pueblo rebellion occurred and the region was deserted. Dr. Kidder, at Pecos, has

verified Mr. Nelson's findings and has extended the history to 1838, when that village was abandoned. In the Rio Grande region corrugated and black-on-white ware lasted until the time when large Pueblo structures were built. Then a gray type of pottery replaced the white and the designs were put on with a black glaze. Somewhat later the body of the designs was painted in dull red and outlined in black glaze. About the time of the Spanish occupation the glaze, for some cause, degenerated, and began to run badly during the firing process. About the time of the rebellion against the Spaniards in 1680, the use of glaze was abandoned and gray colored vessels were decorated with designs in dull red and black. The same general changes also occurred in the Zuñi region. This has been revealed by excavations at Hawikuh by Mr. F. W. Hodge of the Museum of the American Indian, Heye Foundation. In that region also there was a period during which glaze paint was used, which was followed by the manufacture of a polychrome ware.

MODERN WARE

The pottery vessels in the Southwest Indian Hall from the modern Pueblo villages were collected during the last thirty years, the larger number only twenty or more years ago. The striking differences, when these modern vessels are compared with the prehistoric wares, are to be found in the use of red as well as black in painting the designs, and in the prevalence of life forms.

The characteristic Zuñi vessel is an olla, nearly spherical in shape, but flaring toward the neck. The decoration most prized by the Zuñi shows a deer enclosed in a framework which is called his house, and near this a sunflower on which he is believed to feed. In drawing the deer the organs of the throat, mouth, and thorax are indicated, regardless of the fact that they are not in view when looking at the living animal. Scrolls and angular figures in solid color and hatching are also employed. The painting is in black and brownish red on a gray background. By these colors the Zuñi vessel is most quickly identified.

The walls of vessels made by the Acoma, near neighbors of the Zuñi, are sloping toward the bottom rather than rounded. The designs are in black and a yellowish red, often of a floral origin and cover two-thirds or more of the surface of the vessel, the lower portion being left solid red.

Santo Domingo ware is easily recognized by the nearly pure white glossy slip. The designs are usually in black only and are more open or widely spaced than in other modern ware, and frequently are purely geometric. Each village in the Rio Grande valley has in fact certain distinctive features in the shape and decoration of its pottery.

Recently, that is since 1921, a new ware has been made at San Ildefonso. The body of the vessel is a glossy black with the designs in a mat surface. The latter is obtained by the use of a paint which is made by mixing a powdered yellow stone with the syrup of the bee-balm. The ware is very pleasing and has found a ready market.

Among the Hopi, pottery is made at the present time only by the inhabitants of the First Mesa. Some years ago when the ruined village of Sikyatki, mentioned above, was being excavated a woman from the village of Hano named Nampeyo became interested in the pottery being recovered there. She began to manufacture pottery somewhat similar to this ancient ware, getting her inspiration from the designs she found upon it. Great quantities of this pottery are now produced on the First Mesa and sold to tourists. Much of it is quite unsuited to household uses. The older Hopi ware which has now been displaced was decorated in brown, black, and red designs on a dirty white slip which becomes covered with fine cracks.

Beside those described above which are used in the household or sold to tourists, vessels with a portion or portions of the rim projecting and terminating in terraces are made for ceremonial use. The painted decorations are symbolic, consisting of cloud designs and of life forms connected with water. The dragonfly is frequently represented. The cloud design consists of a group of semi-circles from which depend vertical lines indicating rain and with diagonals projecting upward to represent lightning. Such vessels are used to hold cornmeal and other sacred materials needed in the ceremonies.

BIBLIOGRAPHY

BUNZEL, RUTH L. The Pueblo Potter. New York. 1929.

CHAPMAN, K. M. Life Forms in Pueblo Pottery Decoration. Art and Archæology, Vol. XIII, no. 3, pp. 120–122. Washington, 1922.

CUSHING, F. H. A Study of Pueblo Pottery as Illustrative of Zuñi Cultural Growth. Fourth Report of the Bureau of Ethnology, pp. 467–521. Washington, 1886.

DUFF, U. F. The Prehistoric Ruins of the Rio Tularosa. American Geographical Society Journal, Vol. XXIX, pp. 261–270. New York, 1897.

FEWKES, J. W. Archæological Expedition to Arizona in 1895. Seventeenth Report of the Bureau of American Ethnology, pt. 2, pp. 519–742. Washington, 1898.

Two Summers' Work in Pueblo Ruins. Twenty-second Report of the Bureau of American Ethnology, part I, pp. 3–195. Washington, 1904.

Ancient Zuñi Pottery. Putnam Anniversary Volume, pp. 43–82. New York, 1909.

Archæology of the Lower Mimbres Valley, New Mexico. Smithsonian Miscellaneous Collections, Vol. 63, no. 10. Washington, 1914.

Animal Figures on Prehistoric Pottery from Mimbres Valley, New Mexico. American Anthropologist, n.s., Vol. 18, no. 4, pp. 535–545. Lancaster, 1916.

Designs on Prehistoric Hopi Pottery. Thirty-third Report of the Bureau of American Ethnology, pp. 207–284. Washington, 1919.

Designs on Prehistoric Pottery from the Mimbres Valley, New Mexico. Smithsonian Miscellaneous Collections, Vol. 74, no. 6. Washington, 1923.

GUTHE, CARL E. Pueblo Pottery Making. New Haven, 1925.

HOLMES, W. H. Pottery of the Ancient Pueblos. Fourth Report of the Bureau of Ethnology, pp. 257–360. Washington, 1886.

KIDDER, A. V. Pottery of the Pajarito Plateau and of Some Adjacent Regions in New Mexico. Memoirs, American Anthropological Association, Vol. 2, pt. 6, pp. 407–562. Lancaster, 1915.

An Introduction to the Study of Southwestern Archæology. New Haven, 1924.

KIDDER, M. A. AND A. V. Notes on the Pottery of Pecos. American Anthropologist, n.s., Vol. 19, no. 3, pp. 325–360. Lancaster, 1917.

MORRIS, EARL H. Preliminary Account of the Antiquities of the Region between the Mancos and La Plata Rivers in Southwestern Colorado. Twenty-third Report of the Bureau of American Ethnology, pp. 155–206. Washington, 1919.

The Aztec Ruin. Anthropological Papers of the American Museum of Natural History, Vol. XXVI, pt. 1. New York, 1919.

The Beginnings of Pottery Making in the San Juan Area; Unfired Prototypes and the Wares of the Earliest Ceramic Period. Anthropological Papers of the American Museum of Natural History, Vol. XXVIII, part 2, New York, 1927.

NELSON, N. C. Chronology of the Tano Ruins, New Mexico. American Anthropologist, n.s., Vol. 18, no. 2, pp. 159–180. Lancaster, 1916.

PEPPER, G. H. Human Effigy Vases from the Chaco Cañon, New Mexico. Boas Anniversary Volume, pp. 320–334. New York, 1906.

Pueblo Bonito. Anthropological Papers of the American Museum of Natural History, Vol. XXVII. New York, 1920.

PRUDDEN, T. M. A Further Study of Prehistoric Small House Ruins in the San Juan Watershed. Memoirs, American Anthropological Association, Vol. V, no. 1, pp. 3–50. Lancaster, 1918.

SPIER, L. An Outline for the Chronology of Zuñi Ruins. Anthropological Papers of the American Museum of Natural History, Vol. XVIII, pt. 3, New York, 1917.

Notes on Some Little Colorado Ruins. Anthropological Papers of the American Museum of Natural History, Vol. XVIII, pt. 4, New York, 1918.

STEVENSON, J. Illustrated Catalogue of the Collection Obtained from the Indians of New Mexico and Arizona in 1879. Second Report of the Bureau of Ethnology, pp. 307–422. Washington, 1883.

Illustrated Catalogue of the Collection Obtained from the Indians of New Mexico in 1880. Second Report of the Bureau of Ethnology, pp. 423–465. Washington, 1883.

Illustrated Catalogue of the Collection Obtained from the Pueblos of Zuñi, New Mexico, and Walpi, Arizona, in 1881. Third Report of the Bureau of Ethnology, pp. 511–594. Washington, 1884.

1. Pottery Making at Zuñi. The first step after the ingredients have been gathered and freed of foreign materials is to crush the dry clay and tempering materials with a hand stone, thus mixing them.

2. Pottery Making at Zuñi. When the clay and temper have been sufficiently pulverized they are mixed with water to make a paste and kneaded. In the photograph the decorated bowl contains prepared clay; the second bowl, water.

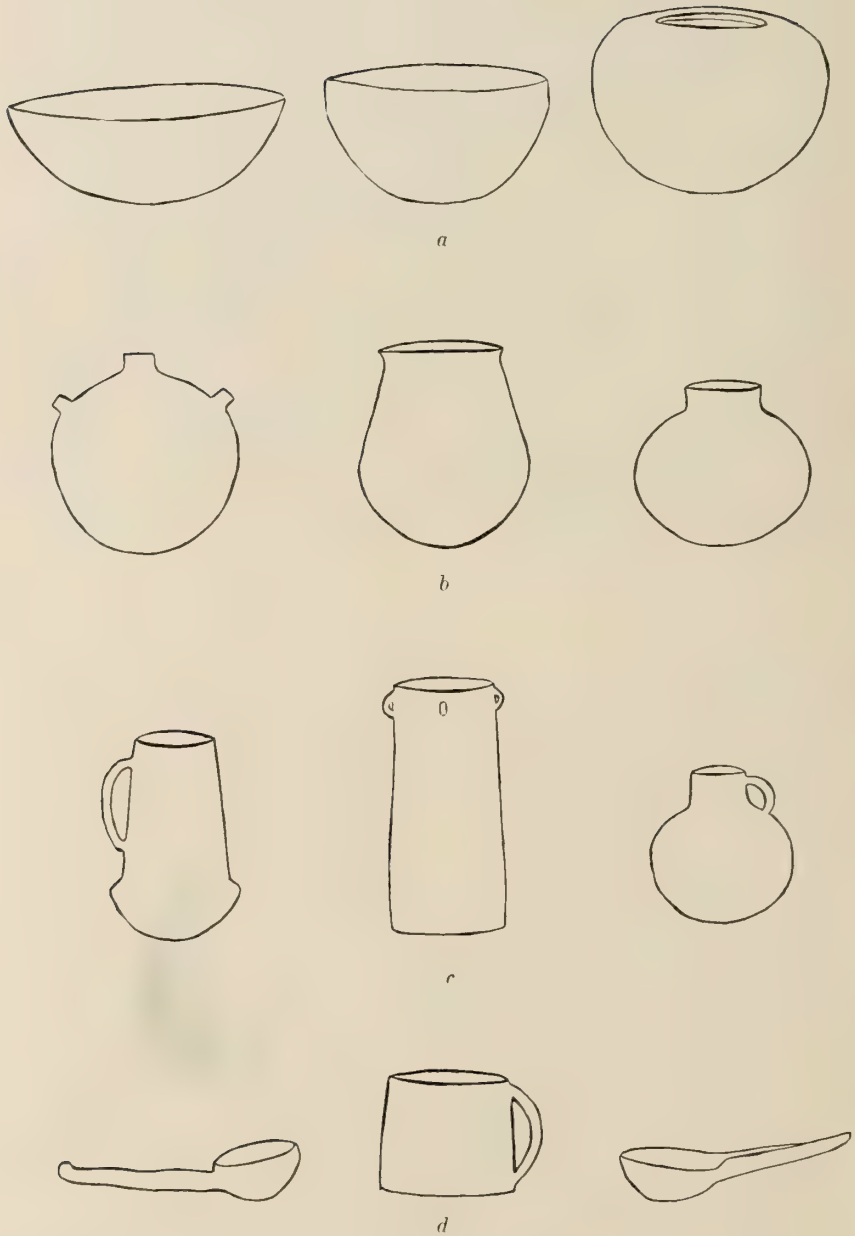
3–4. Pottery Making at Zuñi. The vessel is built up with rolls of clay applied spirally. In the upper illustration the potter is rolling out the clay preparatory to adding it to the already completed lower portion of the bowl. In the lower photograph she is adding a roll of clay with her left hand, while with her right she presses it to the edge of the preceding roll to hold it in place.

5. Pottery Making at Zuñi. When the pot has been built up to the desired size and shape the surface is smoothed with a molding tool. Throughout the process thus far the vessel is held in a base mold.

6. Pottery Making at Zuñi. The vessel has been removed from the base mold and a white slip, contained in the bowl in the foreground, has been applied. Then the white slip is polished with a rubbing stone.

7. Pottery Making at Zuñi. The red and black design is painted with a yucca leaf brush.

8. Pottery Making at Zuñi. The completed vessel is placed in an oven, covered, and fired.



9. Pottery Forms in the Southwest; a, Bowls; b, Ollas; c, Pitchers; d, Ladles and a Mug.

10. A Cooking Vessel of Corrugated Ware from the Aztec Ruin, New Mexico.

11. SHERD from a Basket-Moulded Unfired Bowl with a smooth interior and a plain rim added above the edge of the basket and a large lug. The tempering material was cedarbark.

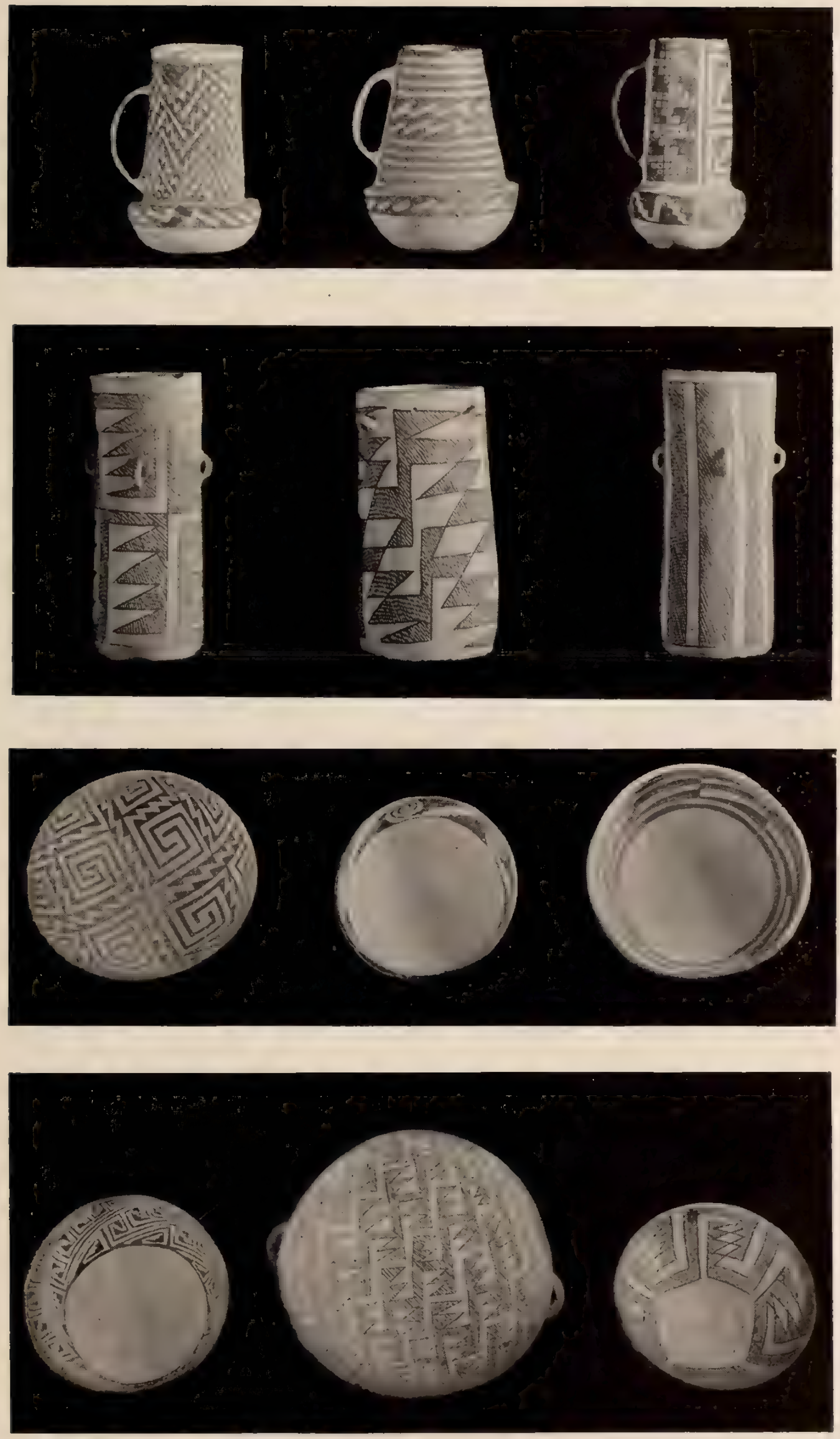
12. Culinary Vessels with Banded Necks, marking the beginnings of the technique later developed in corrugated ware. From graves on the Navajo Reservation.

13. A Bowl with the Decorative Value of the Corrugations further enhanced by the addition of an incised ornamental design.

14. Typical Bowls and Mugs with designs in black on a white ground, from the Aztec Ruin, New Mexico.

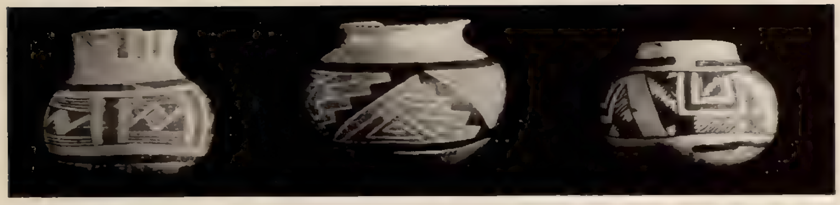
15. a–b, Interior All-Over Decoration on Black-on-white Bowls from the Aztec Ruin; c–d, Types of Zonal Ornamentation on Black-on-white Bowls from the Aztec Ruin.

16. Jars and Bowls of Black-on-white Ware from the Aztec Ruin and Pueblo Bonito, Chaco Cañon, New Mexico.



17. Pitchers, Cylindrical Jars, and Bowls in Black-on-white Ware, from Pueblo Bonito, Chaco Cañon, New Mexico.

18. Bowls in Black-on-white ware from the Mimbres Valley in southeastern New Mexico. Usually this interior decoration consists of one or two wide lines, or a series of fine lines, beneath which is a band of geometric decoration, leaving the bottom of the bowl free to receive distinctive treatment in the form of the realistic animal, bird, fish, insect, or human figures.



a

b

c

19. a–b, Jars and Bowls in Three Colors, Black-and-white on a red slip, from the Little Colorado region; c, Black-on-white pitchers, the commonest form in the Upper Gila Region, with striking interlocking designs and handles often modeled in animal form.

HOPI

HOPI

ZUÑI

20. Modern Pueblo Pottery

PRAYER MEAL BOWLS—SAN ILDEFONSO

STORAGE JARS—SAN ILDEFONSO

21. Modern Pueblo Pottery

LAGUNA

SIA AND SANTA ANA

SANTO DOMINGO

22. Modern Pueblo Pottery

THE AMERICAN MUSEUM OF NATURAL HISTORY

OUTPOSTS OF THE SEA

By ROY WALDO MINER

GUIDE LEAFLET SERIES No. 74

OUTPOSTS OF THE SEA

ANIMALS OF THE TIDAL ZONE

By

ROY WALDO MINER

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A PICTURESQUE CORNER OF A TIDE POOL

A colony of sea anemones (*Metridium marginatum*), is clustered together on a rocky shelf. At the right, one or two anemones, sheltered beneath the floating rockweed, have ventured to expand their fluffy circlets of tentacles. Though of flower-like beauty in color and form, they are nevertheless voracious creatures, armed not only with tentacles but also with sting cells, with which they slay and capture small creatures, and even fishes which form their food. A number of the anemones have contracted, withdrawing mounth and tentacles within their bodies

ANIMALS OF A SUBMERGED SANDY SEA FLOOR

OUTPOSTS OF THE SEA

The Animals of the Tidal Realm—Marine Hosts that Today Assail Our Continental Borders, Endeavoring to Repeat the Conquest Attained Ages Ago by the Ancestors of the Present Land-animals

By ROY WALDO MINER
Curator of Marine Life, American Museum of Natural History

THE daily rise and fall of the tides along the seacoast alternately submerges and lays bare a strip of the shore which varies in width from place to place according to the local range of the tide.

Thus, the vertical rise of the tides off the New England coast south of Cape Cod is only from one to two feet. Within Cape Cod Bay and Massachusetts Bay, on the other hand, it rises nine to ten feet. This is also true along the Maine coast, where the tides are deflected to the northwest by the curvature of the shore, joining the incoming waters farther north. These, in turn, are finally compressed into the narrowing funnel of the Bay of Fundy with the result that huge tides of thirty to forty feet are created at its tip.

In Passamaquoddy Bay, New Brunswick, the rise is twenty-two feet, and this is the extent to which it covers the vertical cliff-walls of Bliss Island, at the entrance to the bay. St. Andrews Point, within the same bay, has a very gradual slope, and, at low water, is uncovered for two miles. Hence, the tidal zone varies greatly in area.

The nature of the substratum composing it also differs. It may be of rock in the form of vertical cliffs, as above mentioned, or sloping and, perhaps, broken into terraces. On the exposed shores it may consist of sand beaches, or mud flats in sheltered coves and bays. It may be covered by rocky bowlders, broken down from the cliffs by wave action, or eroded out from headlands of glacial drift by the washing away of the soil enclosing them.

The animal and plant life of the permanently submerged continental shelf has oveflowed into this stretch of semi-

Photograph by Mary C. Dickerson

A SAND BEACH AT LOW TIDE, WOODS HOLE, MASSACHUSETTS

Long lines of seaweed, thrown up by the waves, are arranged in ribbon-like bands, beneath which sand hoppers and beach fleas are concealed

terrestrial, semi-marine territory. The continental shelf is the submarine continuation of the tidal zone seaward. It slopes gradually to about one hundred fathoms, beyond which the bottom falls more rapidly to the greater depths of the ocean. This outer face of the shelf is known as the continental slope, and varies in its abruptness from a clifflike drop to a gradually accelerated gradient continuing the surface of the shelf itself. The width of the continental shelf also varies considerably. It is extremely wide in the North Atlantic, from the American side around to the British Isles, but quite narrow off Spain and Portugal and the western coast of Africa.

It is believed that the comparatively shallow waters of the continental shelf and slope witnessed the great evolution of marine life. Here it became diversified and abundant, for here the conditions of life are at their best. From this region marine creatures were crowded out into the deeper oceanic waters, on the one hand, or specialized for the pressures and darkness of the deep abysses. On the other hand, they invaded the tidal zone, the fresh waters and, finally, the land. The evidence is strong that wherever and whenever life originated, the continental shelf is the region of its greatest evolution and the center of its radiation. The very fact that its location has shifted during geologic ages, as the continental areas were thrust upward or were worn down again through erosion, until the continental shelf invaded their lower reaches as epi-continental seas, has caused the living creatures inhabiting the shallow waters to be subjected to varying conditions and an intense struggle for existence, resulting in the preservation of adaptive changes and the elimination of those that were nonadaptive. As we see it now, the tidal zone and its inhabitants

represent a present-day phase of that struggle, for here only those sea creatures can exist that are adapted to the strenuous daily changes of environment involved in being alternately exposed to the air and submerged by the tidal flow. It is so striking an example of the results of natural selection on a large scale, and so accessible to everyone, that the thinking visitor to the shore will have no difficulty in reading the chief lessons taught by the inhabitants of the tidal region.

In the first place, it must be remembered that the tidal zone is the pulsating border of the great life-association of the submerged continental shelf. Secondly, life is so abundant that animals and plants of all species not only live where conditions are appropriate and easy for them, but also struggle to live under adverse circumstances. Those that inhabit the totally submerged shallow seas find life comparatively easy, exposed as they are to the sunlight, yet covered by oceanic waters chemically harmonious with their body fluids—a fluid hydrosphere filled with food and replete with oxygen for the animals, and carbon dioxide for the plant life. Nevertheless, many also struggle to live under the more trying conditions of the tidal zone, where they maintain their position in proportion to their hardiness and their capacity to withstand exposure.

Everyone who walks along the shore at low tide is familiar with the zonal or banded distribution of the animal and plant forms. This is especially conspicuous on the rocky shores of New England, north of Cape Cod. The white band of rock barnacles (*Balanus bala-*

THE CLIFFS AT NAHANT, MASSACHUSETTS, AT LOW TIDE

The tidal zone is clearly marked on the vertical rocky face, as a band nine feet in width, showing the white frieze of barnacles above the stratum of seed mussels and rockweed which extends to the water line. A rock tide-pool, overarched by a weed-festooned natural bridge, is shown in the foreground. This locality is reproduced in the American Museum as the "Tide-Pool Group"

A CROWDED COLONY OF MUSSELS AND BARNACLES
Both mussels and barnacles can withstand long exposure to the air by enclosing enough sea water within their shells to keep their breathing organs moist. Together with the periwinkles (*Littorina litorea*) and "purple" snails (*Thais lapillus*), they invade the upper regions of the tidal zone. The snails, especially, suggest a transitional stage toward terrestrial life

noides) is displayed at the summit of the zone, their close-set marble wigwams crowding each other to form a snowy frieze. Ambitious periwinkles (*Littorina litorea*) swarm here and there, climbing slowly but surely upward over the housetops of the barnacle colony, and even mounting far up the bare rocks above it.

The barnacle frieze is overlapped below by the rockweeds (*Ascophyllum nodosum* and *Fucus vesiculosus*), their olive-brown fronds draped in graceful fringes down to the water's edge, disclosing beneath their parting masses the continuous embossed mosaic of the black edible mussel (*Mytilus edulis*), which encrusts the rock up to the lower limit of the barnacle zone. Bright patches of gaily colored and banded "purple" snails (*Thais lapillus*) may be seen grouped upon the mussel colony, which extends downward and below the water mark. Here it is succeeded in turn by another zone characterized by the green sea urchin, a small animal rejoicing in one of the longest scientific names known to zoölogy, *Strongylocentrotus droehbachiensis.*

The sea plants below the rockweed zone include the common pink coralline (*Corallina officinalis*), the Irish moss (*Chondrus crispus*), and the dulse (*Rhodymenia palmata*). These are laid bare only by the lowest tides, and even then are continuously washed by the surf. Also at this level the two species of the common sea star (*Asterias vulgaris* and *Asterias forbesi*) are to be found, the former varying in color through red, orange, purple, and blue, and distinguished by a white spot, the ambulacral plate, between two of its arms. The latter is usually greenish brown, with a bright orange ambulacral plate. Associated with them are the common sea anemone (*Metridium dianthus*) and two species of rock crab (*Cancer borealis* and *Cancer irroratus*).

This zonal arrangement depends upon two main factors, the exposure factor

and the food factor. It is obvious that the height above the low-water mark at which a sea animal can live depends upon its ability to withstand exposure to the air, for the upper limits of the tidal zone are, of course, left bare the longest. The periwinkle, in fact, is far on the way toward adaptation to terrestrial life. As the tide falls, it captures a few drops of water, which bathe its breathing organs and are kept from evaporation by a closely fitting horny plate closing the shell-opening. In this way it may remain many hours out of water. It is a vegetarian, feeding not only on the surface of rockweed, but also on minute algæ high on the rocks and among the barnacles.

The barnacles likewise are provided with means of retaining a few drops of moisture or moistened air beneath four little valvelike plates that close the top of their shells. They feed on the microscopic diatoms brought on the crest of the incoming tide. When they are submerged, each barnacle may be seen to unfold its quadripartite doors, whereupon the little plume of feathery feet waves to and fro, and, like a casting net, captures its tiny prey, which is immediately withdrawn within the closing gates. Agassiz has said that a barnacle is nothing but a shrimp standing on its head within a marble house, kicking its food into its mouth with its feet!

The mussels, occupying the zone immediately below the barnacles, can withstand exposure, but for a shorter time. They, too, feed upon diatoms. Both mussels and barnacles are preyed upon by the voracious "purple" snails, which also can withstand exposure at low tide, though many remain hidden under the moist drapings of rockweed.

The mussel zone is limited above by the barnacles, which tend to spread over the mussel shells and choke them by their more rapid growth, and below, by the zone of green sea urchins, which feed

COLLECTING IN THE TIDE POOL AT NAHANT, MASSACHUSETTS

Basins and crevices in the rocks remain filled with water when the tide falls below their level, and thus harbor not only the life of their own zone, but also many creatures which ordinarily live below the low-tide mark

upon the mussels. The latter are also preyed upon by dog whelks (*Buccinum undatum* and *Lithodomus decemcostata*), two large snails found on our northern rocky shores. The whelks bore round holes into the mussel shells and suck out the animal.

Down near the low-water line voracious sea stars envelop the mussels with their arms, attaching their tube feet to the opposing valves, which they pull apart by gaining a purchase with their arm tips on the surrounding substratum. Then each sea star protrudes its saclike stomach from the central mouth on the underside of its body, and inserting it between the valves of the mussel, pours out its digestive fluid. Thus, it digests the poor creature within its own shells, while it absorbs the fluid products of digestion through its stomach walls. Sea stars devour oysters even more voraciously, and are the most hated enemies of the oyster fisherman.

On terraced and sloping rocky shores there are many crevices and basins that are left filled with water at low tide. These occur at various levels and, in the lower part of the tidal zone, are especially rich in concentrated animal and plant life appropriate to the level at which they occur, and also to all the zones below that level. At flood tide they are invaded by the eggs and larvæ of many creatures usually found only below the low-water mark, which are able to live and develop in the pools because these are always filled with water. Thus the pools become veritable sea gardens of great beauty and fertility.

Here gay-colored sea stars occur in great abundance, hiding in crevices between bowlders covered with velvety brown Irish moss glimmering with iri-

Photograph by Mary C. Dickerson

A SEA ANEMONE WITH BEAUTIFULLY EXPANDED TENTACLES

These flower-like animals (*Metridium dianthus*) live at or below the low-water mark, often in great numbers. Their petal-like circlets of tentacles are armed with sting cells and surround a central mouth. Free-swimming creatures, including small fishes, are caught, stung to death, and devoured. The anemones vary widely in color, from brown through pink, cream, white, and deep orange

descent violet tips and overhung with clustered chimneys of the gray-green crumb-of-bread sponge (*Halichondria panicea*). Feathery, ruby-hearted hydroids (*Tubularia crocea*) fringe a shelf occupied by sea anemones with their rich stock-in-trade of color, ranging from brown, mottled with white, through plain white to rich pink and deep orange.

Two green crabs (*Carcinides mænas*) are sparring with each other in a corner beneath the ruffled overhanging fronds of the brown kelp (*Laminaria agardhii*). The entire rock surface, lining the pool, is gay with sea mosses or encrusted with red-purple and brown calcareous algæ. Thus the pool is replete with life, refreshed and renewed by the periodic incoming tides with their floods of food and oxygen.

Photograph by Mary C. Dickerson

PERIWINKLES AND SEA STARS EXPOSED AT LOW WATER

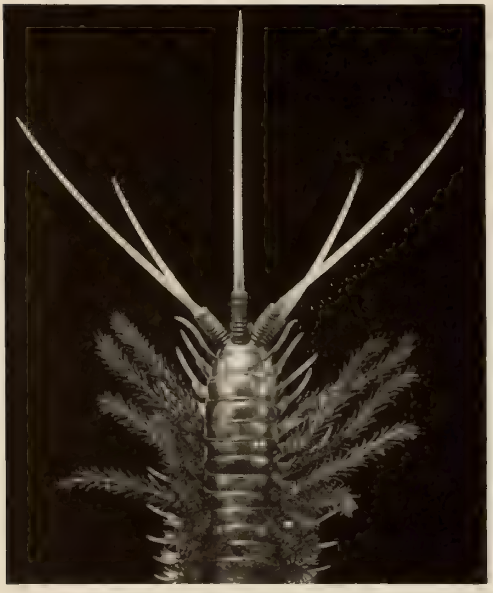
The ubiquitous periwinkles are abundant near the low-water mark, as well as in the upper reaches of the tidal zone. The sea stars, on the other hand, can withstand exposure for only a short time, and are therefore confined to the lower part of the tidal zone and the waters below the low-tide mark

While the northern New England shore is characterized by its rock-bound coasts, sandy beaches occur here and there, hemmed in by granite headlands, and mud flats are found in sheltered locations. But southern New England is typically low and sandy, beginning with the great sand spit which is Cape Cod. This forms a barrier hindering, to a degree, the intermingling of northern and southern forms.

Animals of the rocky coasts and regions of high tides must be adapted for clinging to crevices and for withstanding the battering of the waves and the rush of tidal currents. Animals of sandy and muddy regions, on the other hand, tend to be of burrowing habits, while the surface-living creatures are scavengers.

A sand beach, at low tide, appears to be a particularly barren place. Yet the close observer will detect signs of life. For example, he may chance upon little heaps of sand here and there, which betray the presence of the sand-collar snail (*Natica duplicata*).

If one waits till the tide begins to rise and covers these burrows, a stirring of the sand may be seen, and soon the snail will issue forth and crawl slowly over the



THE PLUMED WORM
This martial looking knight (*Diopatra cupræa*), of the sea bottom, lives in a chimney-like den, the upper portion of which projects into the water above the ocean floor

sea bottom. As it unfolds its foot and expands its "apron," it seems impossible that so huge a creature could have been packed into a spherical shell the size of a tennis ball. Above the apron it waves a pair of tapering tentacles, furnished with eyespots near the base.

The egg-case of this snail is a flat, nearly circular, collar-shaped structure, to which the sand adheres. The underside is completely lined with transparent, beadlike eggs. These sand collars are often picked up on the beach in a dry condition, when they crumble at a touch.

Other burrowing animals of the sand beach are the razor-shell clam (*Ensis directus*), so called from its elongate bivalve shell suggesting the handle of an old-fashioned razor; the lady crab (*Ovalipes ocellatus*), a swimming crab with hind legs terminating in oval paddles and a carapace beautifuly marked with

A FLEET-FOOTED INHABITANT OF SAND BEACHES
The ghost crab (*Ocypoda albicans*) is aptly termed, for its light, sandy markings so closely resemble the color of the beach, that it flits like a shadow along the shore and seems actually to disappear from the sight of the observer when it comes to rest

Photograph by Mary C. Dickerson

A COLONY OF GREEN SEA URCHINS

These sea urchins (*Strongylocentrotus droehbachiensis*) are abundant at or below the low-water mark on our northern rocky coasts. They feed upon the edible mussels (*Mytilus edulis*) and both, in turn, become the prey of the voracious sea stars (*Asterias vulgaris* and *forbesi*)

small purplish spots; and the ghost crab (*Ocypoda albicans*), found on sandy beaches from Long Island southward. This crab makes its burrows above the low-water mark and its whitish carapace so closely imitates the sand that it is difficult to see it, except when in motion. It runs with great speed, and, when it stops, seems to disappear.

Mud flats are especially rich in sea life. Everyone is familiar with the great stretches of edible mussels (*Mytilus edulis*) that are found on certain mud flats between the tides, and the kind of sandy mud in which one digs for clams, whether the soft clam (*Mya arenaria*), or the "hard shell" (*Venus mercenaria*).

But let us take a water glass (which is just a bucket with a glass bottom), and wade at low tide in a sheltered cove near the edge of a patch of eelgrass. Where the shallow sea floor is composed

A MEMBER OF THE STREET-CLEANING FORCE OF SHALLOW WATERS

The hermit crab (*Pagurus pollicaris*) is one of the scavengers of submerged, muddy sea bottoms

SEA STAR DEVOURING OYSTERS

The sea star mounts the shells of the living oyster with its five arms partly enfolding the two valves of its victim. It then applies its hundreds of tube-feet to the outer surface of the shells by means of small terminal suckers. With the tips of its arms it braces itself against the surrounding objects and exerts a strong, steady pull, that gradually forces the oyster shells apart

of sandy mud, let us place the water glass on the surface and look through it. A busy scene at the edge of a miniature submarine forest composed of the eelgrass roots, is disclosed to our eyes. Tiny hermit crabs (*Pagurus longicarpus*) are scuttling to and fro. Soon they gather about a bit of decaying substance and immediately begin to pull it apart. Mud snails (*Nassa obsoleta*), attracted by the tumult, crawl up from various quarters, leaving a little groovelike track in the mud behind them. A larger hermit (*Pagurus pollicaris*) lumbers along and scatters the smaller fry as he pulls the decaying morsel to pieces. Small, transparent shrimp (*Palæmonetes vulgaris*) dart in to get their share.

The hermits, the shrimp, and the mud snails are the scavengers of shallow water —the street-cleaning department of the submerged mud flat—and they are thorough in their work. It is true that the hermits acquire their uniforms by theft, for they appropriate the shells of sea snails. Sometimes they find them empty and ready for use. At other times, they are said to eat out the former occupant first, thus obtaining a meal and a home simultaneously. When they grow too large for the shell they happen to have, they hunt for another, and it is amusing to see them make the change. They leave the old shell and, quickly settling into the new one, try it a few seconds, then change back to the old home. After a short interval the new shell is tried again, and the process is repeated several times. In the end, the hermit may walk off with the old shell after all!

We now direct our gaze at the shallow

sea floor in the clear space between the eelgrass and the shore. Here on the sandy mud we begin to see certain details that hitherto have escaped our attention. Clusters of broken shell and bits of sea-weed, apparently caught together by the currents, now resolve themselves into neatly cemented chimneys leading to some underground abode, for gently waving filaments projecting from the summit betray the existence of an occupant.

We carefully dig down into the sea bottom around the structure and remove a long, tapering, parchment-like tube, with the thickened chimney of shell-fragments at the top. After washing it, we cut it open in a glass dish of sea water, and out floats a beautiful, struggling creature, clad in segmented steel-blue armor, and bearing several sets of blood-red plumes upon its shoulders, while five tapering, lancelike palps are flourished in front. This knight of the submarine castle is the plumed worm (*Diopatra cupræa*).

Likewise, paired chimneys of smoother texture a little nearer the shore cause us to dig up a U-shaped tube, also of parchment, belonging to the parchment worm (*Chætopterus variopedatus*). This is the most curious worm of all. It is a strange creature with a flat, shovel-like head, armed with bunches of golden bristles, behind which is a pair of long arms having grooves lined with moving cilia. Then comes a pulsating cup, attached to the upper side of the body, followed by three disc-shaped segments, and last of all is the tapering tail, disclosing through its transparent walls an internal structure brightly colored green, yellow, and pink.

The parchment worm lives in the bottom of its tube, the three disc-shaped segments fitting the cavity neatly. As

A BUILDER OF SUBWAYS BENEATH THE SEA

The parchment worm constructs for itself a U-shaped tube formed of a gluelike secretion from glands in its own body, which hardens into a parchment-like substance upon contact with the sea water. The strange looking architect lives in the bottom of his home, the two chimneys of which project into the sea. By means of three disclike segments in the middle part of its body, which just fit the interior of the tube, the creature pumps a stream of water into one chimney and out through the other, from which it abstracts the microscopic creatures that form its food

ANIMALS OF THE WHARF PILES

The piles of old wharves along our shores are completely covered with a great diversity of animal forms, all of which are adapted to filtering out the microscopic food from the sea water in which they are submerged

the worm contracts its body rhythmically, these segments move like the pistons of a suction pump, drawing a stream of water into one chimney, passing it through the tube, over the body of the worm, and out the other chimney. The microscopic food contained in the sea water is filtered out by the combined action of the arms and moving cup, and transported through a trough lined with moving hairs up the mid-line of the body to the mouth of the worm.

It is obvious that not only the sea bottom, but the soil beneath the sea as well, is alive with myriads of creatures, adapted by their structure for breathing and obtaining their food in this particular habitat. Likewise, if we examine the wharf piles of an old wharf, we shall find it clothed completely with sea grapes, tube-building worms of brilliant, flower-like hues, feathery hydroids, scarlet sponges, mussels, sea anemones, members of every animal phylum, all adapted to a stationary form of existence, equipped with various contrivances for extracting minute creatures for food from the life-giving sea in which they are bathed.

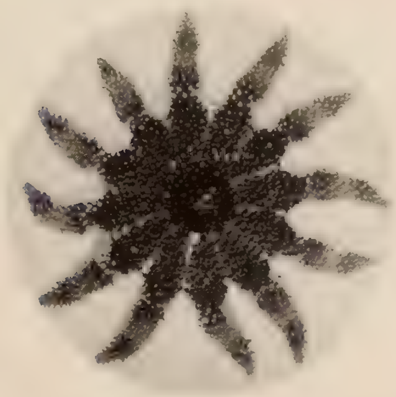
Life pulsates wherever we search along the borders of the sea. Living creatures endeavor to occupy every kind of habitat, and, if it is favorable, swarm through it so vigorously that all the space is occupied and many are crowded to the limits where marine life is precarious.

The pressure to escape to an air-breathing existence drives certain species to the limit of the tidal zone, so that we see, at the present time, compromises between the marine and terrestrial form of life, as in the case of the periwinkles and purples among mollusks. These are closely related to other snails (*Ampullaria* and *Siphonaria*) which have both water-

breathing branchiæ and air-breathing lung, and finally the snails, *Cerithidea* and *Cyclophorus*, terminate the series with a complete air-breathing apparatus. The same pressure now continues which, in the Carboniferous Age, forced the conquest of the air by the lowly progenitors of the land vertebrates.

The comparative anatomy of marine invertebrates shows us that there has been a gradual closing of the body cavity and circulatory system in higher marine animals, thus segregating the body-fluid which bathes their tissues and is closely similar in composition to the salt solution that we call sea water. It is very significant that the inorganic salts of the blood of terrestrial animals are the same as those found in the ocean.

Thus the water of the seas, closely adapted in its composition for the life requirements of the lowest marine creatures and circulating freely through their cavities, has been succeeded by a fluid closed off from the outside within the bodies of higher organisms, some of which finally shook themselves free of their ancestral abode and emerged into the upper air. It is almost as if the invaders of the land carried a portion of their original habitat enclosed within them to bathe their tissues with the precious sea environment and so insure their continued existence in their new world.



THE SUN STAR OF OUR NORTHERN SHORES

This brilliant creature, (*Solaster papposus*), bright scarlet with white-banded arms, is one of the most conspicuous inhabitants of our rocky coasts

HOW OLD IS THE EARTH?

BY CHESTER A. REEDS

GUIDE LEAFLET SERIES, No. 75

THE AMERICAN MUSEUM OF NATURAL HISTORY

NEW YORK, N. Y.

Reprinted from Natural History, March-April, 1931

THE INNER GORGE OF THE GRAND CAÑON OF THE COLORADO RIVER

From a Painting by Gunar Wildforss, 1930

LINCOLN ELLSWORTH COLLECTION

VIEW looking west-northwest across the mouth of Bright Angel Cañon from near the Kaibab Suspension Bridge. The Colorado River is in the left center, and flows here at an elevation of 2450 feet above sea level. The varied rocks of the north wall of the inner gorge appear in the foreground and in the mid-distance, with the isolated Tower of Set, 5997 feet, appearing in the background, left center. In the right center the towering mass of the Cheops Pyramid, 5350 feet, crowns the slope to the inner gorge. The twin peaks of Isis Temple form the highest elevation 7028 feet, in the right background. To the south of the river in the left margin appears a portion of the rocks in the south wall of the inner gorge with the isolated peak of Dana Butte, 5025 feet, prominently in the background.

The geological section, which is of special interest, is explained more fully in the article "How Old Is the Earth ?"

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The Colorado River at the Bottom of the Grand Cañon of Arizona

HOW OLD IS THE EARTH?

The Earth Reveals Its Age By Hour-glass Deposition of Sodium and Sediments, and the Atomic Disintegration of Radioactive Elements

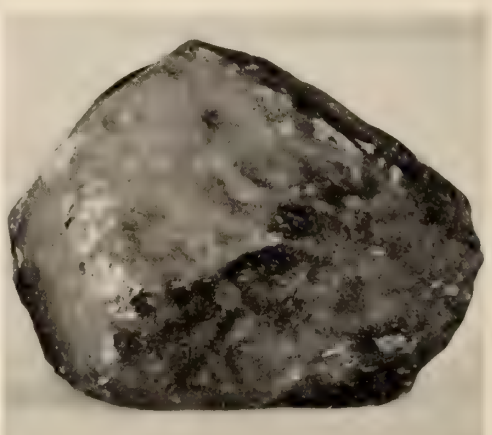
By CHESTER A. REEDS
Curator of Geology and Invertebrate Palæontology, American Museum

IT may be stated at the outset that nobody knows just how old the earth is. There are certain criteria available, however, which indicate that the oldest rocks are of the order of 2000 million years. There are data which imply that the upper limit of the age of the minerals is about 3000 million years. This may be considered the lower limit of the age of the earth's material. Iron meteorites have been analyzed which yield a maximum age of 2600 million years. These are stupendous figures. The lower figure of two billion years as a minimum age for the earth implies that it has encircled the sun as many times, and that during this period it has turned on its axis 730,500,000,000 times to afford as many days of light and darkness.

The presence of ripple marks, sun-crack impressions in muds, water-worn pebbles, rounded sand grains, seasonally banded clays, limestone deposits, and vestiges of primitive forms of life in rocks of very ancient origin, all point to physical conditions on the surface of the earth that are similar in every respect to those enduring today. Various folded gneisses and schists, without vestiges of life, much distorted and frequently impregnated with volcanic injections, constitute the oldest rocks exposed on the earth's surface. The earth, although very old, has a remarkable history. The various steps in its development are in some instances still obscure, but they are becoming more apparent with the growth of knowledge concerning the earth.

Spectroscopic analyses reveal that 49 of the 90 chemical elements found on the earth have been recognized in the sun. In fact, astronomy teaches that the 1091 members of the solar system have originated from the same material. Various theories as to the origin of the earth postulate that the earth and the other

planetary bodies in our solar system were born of our sun when it was in a giant-star stage. This transformation of the sun is supposed to have been induced by the close approach of a passing star several times more massive than the sun itself. The resulting effect of such a close approach was the setting up of great tidal stresses in the sun and the drawing out of two long filaments of gaseous matter from opposite sides of the sun's surface. After the large star passed on, the filament on the far side of the sun as well as a portion of that on the near side may have been drawn back into the sun; however, a considerable portion of the filament remained in space subject to the influence of the sun. In the course of time the matter in this filament was gathered together about certain nuclei to form the nine planets and their satellites. The material was originally in a gaseous state. Later it passed to a liquid state through loss of heat by radiation from its surface, and finally, as in the case of the earth, into a solid state, at least for the outer crustal portion which may be 40 miles in thickness or about 1/200 of the radius of the earth.



American Museum of Natural History

A STONE METEORITE, JOHNSTOWN, COLORADO, METEORITIC SHOWER

This stony meteorite weighing 42 lbs. 8 oz., was seen to fall following four explosions, at 4:20 P.M., July 6, 1924. It is coated with a thin black crust. The gray stony matrix of the interior is shown by the white spots where the crust has been peeled off

The meteors, which enter the upper levels of the earth's atmosphere in great numbers, estimated to be 20 million per day, may be remnants of the original filaments, or of like matter from outer space. Most of these meteors are small, one to two-tenths of an inch in diameter. Upon entering the earth's atmosphere they travel at planetary velocities varying from 9 to 47 miles per second. Due to the great resistance offered to their passage by the earth's atmosphere, which is estimated to be 90 to 100 miles in thickness, the solid portions of most meteors burn up before reaching the earth. In addition to the ash of burnt-out meteors a minimum of one meteorite per day reaches the earth's surface.

The portions of 700 meteoritic falls exhibited in various museums are composed primarily of either nickel-iron, or of stone specimens, or, of combinations of these two kinds of matter. The stony meteorites resemble the light colored felsitic lavas of the earth. There are differences in texture in each, however, which the skilled observer readily detects. The iron meteorites with nickel, troilite, carbon, and other inclusions are not found duplicated on the earth. Some 29 elements found on the earth have been detected in meteorites. On the other hand, six mineral compounds have been noted in meteorites, which have not been found on the earth.

It may be stated thus that the earth, the meteorites, the sun, the moon, and the stars are distantly related. The earth and its moon with diameters of 7918 and 2162 miles, respectively, are intimately related to the sun, which is 866,400 miles in diameter. Although their densities, as compared with equal volumes of water, vary, the density of the earth being 5.52, the moon 3.40, the sun 1.39, these differ-

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THE MYSTIC POWER OF THE COLORADO RIVER IN ARIZONA

A view from the upwarped plateau rim, 7000–8000 feet above the sea, into the outer and inner gorges of the Grand Cañon where the river flows at a level of 2400 feet. This cañon is 217 miles long, from 8 to 20 miles wide, and more than a mile deep. It was eroded by the river during the last one million years

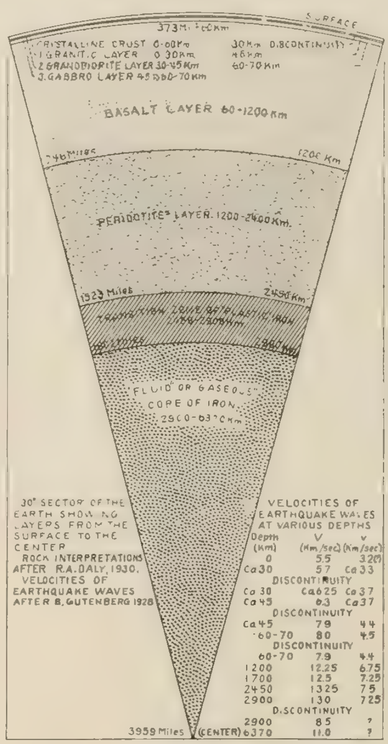
ences are explained by the different states of like matter, the earth and moon being solid and the sun gaseous. The fact that the earth rotates on its axis at a rate of 18.5 miles per second, and about the sun at a rate of 66,000 miles per hour, also implies that the mass of the earth, which weighs 6590 million million million tons, is controlled by the larger mass of the sun, which revolves once on its axis in 25 days, and weighs 1.983×10^{33} grams.

The various stages involved in the upbuilding of the earth are of interest in discussing its age. No two theories agree, however, on the number of steps involved, nor in the way in which it was accomplished, yet most of them assume that in the beginning the materials of which the earth is composed were in a gaseous state. The number of years required for a planet having the size and density of the earth to pass from a gaseous to a solid state is of course problematical.

According to the Planetesimal Hypothesis proposed by the late T. C. Chamberlain and F. A. Moulton of the University of Chicago in 1905, all but the central core of the earth, which is 4346 miles in diameter, has been built up by the infall of planetesimal matter. Since but a small amount of such planetesimal, or meteoric matter, is now added daily to the earth, the hypothesis implies a great age for the earth. Chamberlain held that at the present rate of fall it would require 1,000,000,000 years to form a layer of meteoritic material one inch in thickness on the earth. J. Barrell (1923) took exception to Chamberlain's views and argued for a molten condition of the earth at the completion of its growth. He assumed that the earth developed rapidly by the infall

of planetoid-like bodies rather than by the slow accumulation of dustlike particles. He was of the opinion that all of the near-by planetoids, even those several hundred miles in diameter, except the moon, had been gathered in by the time the earth attained a condition of stability and completed growth.

Present knowledge of the earth indicates that it has a shell-structure. The past thirty years of seismological research have led to this definite conclusion. Besides the solid crust which is composed of a somewhat heterogeneous mixture of sedimentary, igneous, and metamorphic rocks, there are successive zones of material and a central core which differ from one another in density, in chemical composition, and in elasticity. The earth as a whole is more rigid than steel. Earthquake waves are transmitted through it. Each earthquake records three principal kinds of waves on a seismograph, namely: primary, secondary, and main waves. The primary or longitudinal waves pass through all portions of the earth. The secondary or transverse waves, a kind developed only in solids, pass through only the outer portion of the earth; they do not pass below a depth of 2900 km. It is at this depth, 0.45 of the radius of the earth, that the inner core begins. Since this type of wave is not transmitted through the inner core, this portion of the earth is believed to be in a liquid or gaseous state. The main waves which are the largest and last to be recorded, are confined to the crust of the earth.



A 30° SECTOR OF THE EARTH

SHOWING LAYERS FROM THE SURFACE TO THE CENTER. THIS DIFFERENTIATION OF THE INTERIOR OF THE EARTH INTO ZONES IS BASED UPON VARIATIONS NOTED IN THE TRANSMISSION OF EARTHQUAKE WAVES THROUGH THE EARTH. THE INNER CORE DOES NOT TRANSMIT THE SECONDARY OR TRANSVERSE SEISMIC WAVES, A KIND DEVELOPED ONLY IN SOLIDS, HENCE, IT IS BELIEVED TO BE IN A "LIQUID" OR "GASEOUS" STATE

The velocity of the primary and secondary waves at various depths, V and v respectively, as determined by B. Gutenberg, 1928, and the nature of the rock in the respective zones, as interpreted by R. A. Daly, 1930, are given in the accompanying sketch of a 30 degree sector of the earth. The density of the various zones is noted in the text below.

It may be noted that the crystalline crust is 60-70 km. in thickness. In addition to the outer sedimentary layer, which varies in thickness from 0-5 km. with density 2.7, the crust is composed of three zones of rock each separated by planes of discontinuity as follows:

(1) granitic layer 0-30 km. in thickness, density 2.7

(2) granodiorite layer 30–45 km. in thickness, density 2.7+

(3) gabbro layer 45 to 60-70 km., density 2.9.

Below the crust lies a hot, vitreous, basaltic layer 60-1200 km. in thickness, density 3.3. This is followed by a layer 1200–2450 km. in thickness, which Daly believes may partake of the nature of peridotite, while H. Jeffries (1929) refers to it as the dunite layer, density 5.0. At a depth of 2450–2900 km. there occurs a zone composed perhaps of plastic iron,

density 9, where seismographic waves slow down. This would indicate that it is transitional in character from the more or less silicate layers above to the great inner core of the earth below. The inner core with great pressures and temperatures resulting from its superimposed load is believed by H. Jeffries (1929) to be liquid iron, by Daly (1930) to be in a "fluid" or "gaseous" state. Its average density is 11.5. It is probable that the inner core of the earth was originally composed of material resembling that found in iron meteorites. Iron meteorites have a specific gravity of 7 or higher. The idea of a liquid inner core is supported by present-day seismology, for the secondary or transverse wave of an earthquake, a kind appearing only in solids, is not transmitted through the inner core.

The methods of palæogeography afford theoretically a splendid insight into the successive geologic stages involved in the upbuilding of the earth. If one could visualize, even in the crudest fashion the changes in geography that have taken place at regular intervals, say 100,000 years, the sequential history of the earth would be in large measure solved. In accordance with the normal sequence of events such a series of pictures should begin with the birth of the earth, from the parent body, the sun. One hundred thousand years later a sufficient change would have taken place in the earth to depict the second scene. A large number of pictures would have to be sketched, 30,000 in fact, if the earth is three billion years old, before the present day is reached, with its magnificent panorama of continents, oceans, irregular coast lines, mountains, plateaus, plains, rivers, lakes, seas, snow fields, glaciers, deserts, and various forms of plant and animal life,

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HERMIT CAMP AT THE END OF THE HERMIT TRAIL, GRAND CAÑON

This tourist camp, 3700 feet below the south rim, is a half mile east of Columbus Point, the imposing central rock tower. This towering spur is composed of horizontal sediments that are green, mauve, red, and gray in color. The camp overlooks the inner gorge of the Colorado River, 700 feet deep

FOOTPRINTS OF A LABYRINTHODONT, COCONINO SANDSTONE, GRAND CAÑON
Footprints made by an amphibian of Permian age as the sands of the Coconino formation were being deposited 210 millions of years ago. The sands were moist when the impressions were made. The weight of the animal compacted them and the footprints were covered and preserved

not to mention the cities and other works of man.

No fault is to be found with the idea, for geologic processes are continuous and they have been so throughout the immensity of geologic time. The difficulty in preparing such a series of pictures arises from the fact that the records of past events, which are preserved in the earth itself, are somewhat fragmentary and, furthermore, they are not dated in terms of years, as man dates his present chronology.

The data most frequently used in estimating the age of the earth are those based on geologic processes such as erosion, sedimentation, and deformation. These processes are in evidence on the surface of the lands. For epochs, other than the present, these data are to be found in the stratigraphic record as preserved in the crust of the earth.

The rate of erosion of the lands is of value as a criterion. Samples of water from representative streams for various climates and topographic reliefs have been taken and analyzed. From more than 8000 analyses F. W. Clarke in his *Data on Geochemistry*, 1924, observes that taking the continents as a whole they are lowered by solvent denudation one foot in 30,000 years. From measurements of the suspended matter collected in the analyzed samples he concludes that the chemical denudation represents but 30 per cent of the total denudation. This gives a mean rate of total denudation at the present time of one foot in 8600 years.

The average height of all lands above sea level has been computed to be approximately 2300 feet. The average depth of the oceans is about 13,000 feet. If the land surface is lowered one foot in 8600 years and the average height of land above the sea is 2300 feet then it would take 19,780,000 years to erode the lands to sea level, assuming that the rate continued uniform to the end, which is not likely. Granting that the oldest rocks on the surface of the earth are approximately 2,000,000,000 years old, that the rate of erosion continued to be one foot in 8500

years throughout all this time, and that the lands were uplifted at the close of each complete erosion period, then the lands would have to have been uplifted 101 times to afford continuous erosion.

The American geologists, Powell, Dutton, and Davis, have shown that the lands have been base-leveled frequently during geologic time. To this level surface Davis applied the term peneplain. Each peneplain was developed as the result of a cycle of erosion. Many ancient peneplains lie buried and preserved as unconformities between different beds of sedimentary rock; others have been elevated and more or less destroyed by later cycles of erosion. These later cycles are uncompleted, since before any one of them could be finished the lands were uplifted and a new cycle inaugurated. In fact no extensive peneplains, not uplifted or dissected, are known to exist at the present time.

Nevertheless, it is apparent to geologists that the earth has been in repose repeatedly, as far as denudation is concerned; at such times shallow seas have spread far and wide over base-leveled lands; new areas of deposition have thus arisen; sedimentation accompanied by slow subsidence in well defined troughs followed; then folding, crumpling and overthrusting of the horizontal strata appeared as the result of lateral compression; this was followed by a general uplift of the folded rocks into high mountains by forces acting from beneath the crust. Such uplifts were frequently accompanied by the intrusion of igneous and volcanic rocks into the distorted mass. With the uplift of the region a new cycle of erosion was inaugurated, the agents of erosion again renewed their efforts to reduce the new landscape to a peneplain. This in brief is the history of various regions of the earth's crust, particularly where numerous old and young mountains exist.

While the rate of denudation in the various cycles of erosion has not been preserved, the sediments that were deposited in the shallow seas lying upon and about the margins of the continents and

FOSSIL ALGÆ IN A ROCK WALL, PHANTOM RANCH MESS HOUSE, BRIGHT ANGEL CAÑON, ARIZONA
The algæ in this isolated block of Bass limestone from the Unkar group, middle Proterozoic, led to the discovery, 1927–1930, by Dr. David White and Mr. Lincoln Ellsworth, of additional specimens of these ancient lime-secreting plants

in the depressed troughs have been preserved, except where erosion removed all or a part of the uplifted beds. Due to the shifting of the areas of deposition for different epochs the entire series of these sedimentary strata, which total some 529,000 feet or 100 miles in thickness, are not all to be found at any one place, but in different places upon the face of the earth.

Where the erosion of the lands by rivers proceeded in cyclical manner, the deposition of the transported land derived sediments in marine basins followed in accordance with cycles of sedimentation. Conglomerates and sandstones were laid down near shore and at the base of the series; shales and limestones were deposited farther out, or on top of the more coarsely bedded sediments as the rivers became longer or less active, with gentler grades and greater sorting powers.

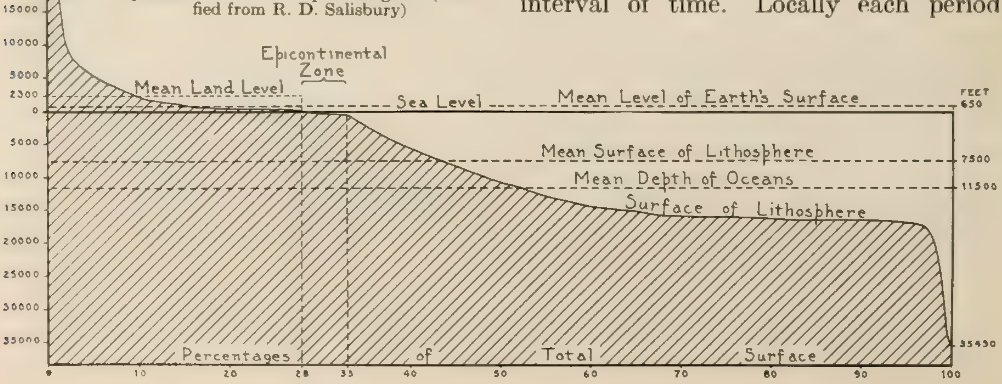
The various forms of animal and plant life which lived in the sea at the time the deposits were laid down were entombed, as they died, by the incoming sediments. Their remains constitute the fossils of the sedimentary rocks. Different species and different forms of life are found in rocks, not only where they were deposited in regular sequence, but in areas where a more recent formation extended over older rocks and a gap in time and in sedimentation was recorded thereby. Fossils are invaluable to the stratigrapher, for where a regular sequence of beds occurs the changes in the species, from bed to bed, permit the establishment of a faunal scale and this may be used elsewhere in deciphering the relations of beds where the sequence may be different or where the character of the rocks may have changed.

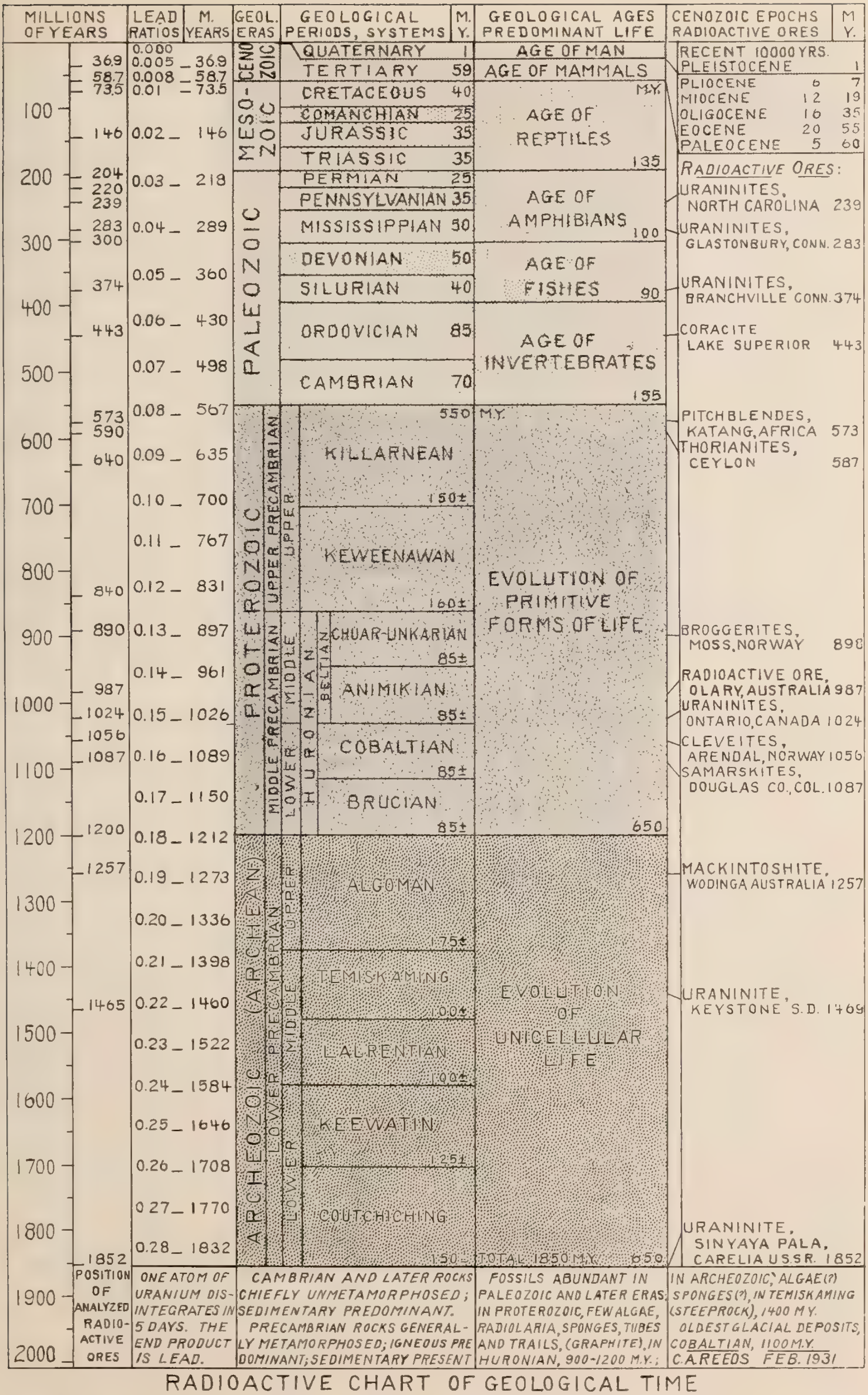
Beginning with William Smith in England in 1796, geologists have built up a geological time scale, the major features of which are applicable to the known rocks of the world. Smith, as a local surveyor, came to recognize beds of rock from place to place by the fossils which they contain. By continued observation over a number of years and much traveling, he was able in 1815 to publish a geological map of England and Wales on which he showed the distribution and succession of rocks of different ages. The local names which he applied to the beds have remained in use to this day.

The geological time scale, as now recognized, is the work of many geologists. It is a kind of chronological chart with various subdivisions, the oldest rocks appearing at the bottom, the youngest at the top. It is the geologists' alphabet. The terms ending in *zoic* refer to eras of life, which constitute major divisions. Each era is divided into periods, which are based upon a definite series of rocks representing one or more cycles of sedimentation, developed during an undefined interval of time. Locally each period

THE RELATION OF THE ROCK SURFACE OF THE EARTH TO SEA LEVEL

A diagrammatic representation of the relative areas of the rock surface (lithosphere) at various levels above and below sea-level, expressed in feet and in percentages. (Modified from R. D. Salisbury)





RADIOACTIVE CHART OF GEOLOGICAL TIME

Note: For every 1,000,000,000,000 uranium atoms (or a mass weighing 1/40,000,000,000 of a gram) one atom explodes every five days. Five eras are shown on this chart; see page 146 for radioactive clock of geological time, showing seven eras.

Ewing Galloway, N. Y.

INNER GORGE OF THE GRAND CAÑON, ARIZONA

View as in frontispiece. Looking down the Colorado River from the Kaibab suspension bridge. Rock section from river bed to top of Isis Temple: *Archeozoic:* V. Vishnu schist; *Proterozoic:* B. Bass limestone; H. Hakatai shale, Sh. Shinumo quartzite; *Palaeozoic:* (Cambrian) T. Tapeats sandstone, BA. Bright Angel shale; (*Mississippian*) R. Redwall limestone, (Permian) Ss. Supai sandstone and shale, C. Coconino sandstone

and system of rocks is further divided into epochs and formations of rocks. These local designations, which are numerous and variable from place to place, have not been included in this general chart.

To illustrate the meaning of portions of this chart the wonderful section of rocks exposed in the Grand Cañon of the Colorado River in Arizona may be cited. Across a plateau, the upper surface of which rises from 7000 to 8000 feet above sea level, the Colorado River has eroded a trench about 217 miles long and a mile deep at the western end. This trench consists of two conspicuous features, one, an outer cañon, which is 4600 feet deep from the north rim and from 8 to 20 miles across, the other, an inner gorge which is another 1000 feet deep, narrow, and V-shaped in cross section. The buttressed walls of the outer cañon are composed of a succession of horizontally stratified sedimentary rocks; limestones, sandstones, and shales representing the Permian, Mississippian, and Cambrian periods of the Palaeozoic era. Below these level strata the river has cut its inner gorge through tilted sedimentary rocks; quartzite, limestone, and shale, some two miles thick, which are of Middle Proterozoic age. Below this series the river has cut its way into a crystalline basement rock, without stratification, which belongs to the earliest era, the Archæozoic. While this great section is wonderfully impressive to those who visit the Cañon, the story has been but partly told.

The ancient basement rocks are separated from the overlying Proterozoic series by a great erosion interval. This interval is represented in the section by an uneven surface known as an unconformity. Prior to occupying their present position, these basement rocks in the bed of the river

which are 3000 feet above sea level, were deeply buried, crushed, smashed, and recrystallized by the processes of diastrophism as they lay at a lower level beneath a thick cover of rock. This cover was removed slowly by surface weathering, wind, and running water, acting throughout a complete cycle of erosion. The present erosion of the Grand Cañon is but a small beginning as compared with the great erosion period under consideration which was completed perhaps 1,200,000,000 years ago.

On top of the gently subsiding peneplain thus established, sediments of the Proterozoic Chuar and Unkar series were slowly deposited. It was a long enduring period, for the deposits are more than 11,000 feet in thickness. The sediments were at least partly of marine origin, for Dr. David White and Mr. Lincoln Ellsworth have collected primitive forms of plants known as fossil algæ, from the Bass limestone, which appears just above the base of the Unkar series. These are the oldest fossils in the Grand Cañon.

Following the long period of deposition, diastrophism renewed its activities. The Proterozoic series was faulted and tilted, in fact, great block mountains thousands of feet in height were uplifted.

This epoch of mountain uplift was followed by a second long period of erosion, during which time the region was again worn to a smooth plain, except for a few low lying hills. In many places the thick Proterozoic series was entirely removed and the basement rocks again exposed except where a few downfaulted blocks of the Proterozoic rocks were preserved. These downfaulted blocks of sediments are all that remain of the great Proterozoic era in

SILICIFIED FORMS OF FOSSIL ALGÆ IN THE BASS LIMESTONE

Collected by Mr. Lincoln Ellsworth from the middle Proterozoic rocks, near the mouth of Bright Angel Cañon, Arizona. This specimen is of exceptional interest to students of the early remains of life. The Radioactive Chart of Geological Time indicates that it is about 940 million years old

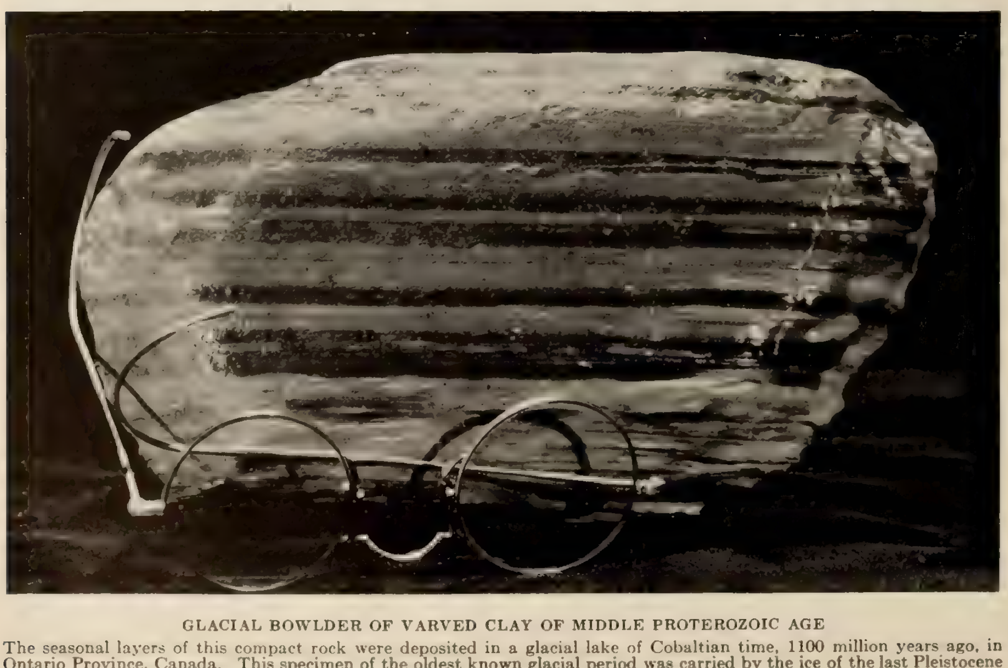
this region. A second great line of unconformity separates the Proterozoic rocks from those of Palæozoic age.

As the land again sank, the seas of Cambrian time rolled in over the smoothed plain to inaugurate another great era of deposition in this region, the Palæozoic. Horizontally disposed sandstones, shales, and limestones were deposited. Amongst them may be found the fossil shells of various invertebrates, the tracks and remains of trilobites, et cetera. In the wonderfully impressive Palæozoic series of beds, the Orodovician, Silurian, and Devonian periods are missing. They are represented by an unconformity. We shall know more about what happened to them when the Grand Cañon is more fully explored.

As one views the Grand Cañon from the rim at El Tovar, it is difficult to realize that the rim rock, the Kaibab limestone, of Permian age, is not the top of the series of sediments. The great cliffs on the north and east that overlook the region are the higher strata that once extended over the whole district of the Grand Cañon. The distant strata represent deposits of Permian, Mesozoic, and Tertiary age. They are about a mile in thickness. Two major cycles of erosion are preserved in these rocks, one at the end of the Permian, the other at the close of the Mesozoic era. Each denotes prolonged erosion and a great interval of time. This Grand Cañon section, although extremely interesting and impressive, represents but portions of the geological time scale.

We have now suggested briefly the part played by the great geologic processes during the upbuilding of the earth. The question arises how long have these forces been acting? While various criteria have been used in the investigation of this problem, the data most frequently consulted are the sodium salts of the oceans, the thickness of the sedimentary rocks, and the radioactivity of the igneous rocks.

The sodium in the oceans has been derived from the land by the weathering of igneous rocks. It has been transported



GLACIAL BOWLDER OF VARVED CLAY OF MIDDLE PROTEROZOIC AGE

The seasonal layers of this compact rock were deposited in a glacial lake of Cobaltian time, 1100 million years ago, in Ontario Province, Canada. This specimen of the oldest known glacial period was carried by the ice of the last Pleistocene glaciation to Battle Creek, Michigan. E. M. Brigham collector

from the land to the sea by rivers carrying it in solution. As noted by J. Joly of Dublin in 1899, the mass of the ocean waters is 1,180,000 million million tons. The percentage of sodium in the oceans was calculated by him to be 1.08 per cent by weight, so that there are 12,600 million million tons of sodium in the oceans. The amount of sodium contributed by the rivers to the sea annually has been variously estimated. After applying certain corrections, A. Holmes, 1927, calculated that the yearly increment amounts to 35 million tons. The amount of sodium in the sea divided by this annual rate gives 360,000,000 years as the age of the oceans.

VARVED CLAY OF LATE PLEISTOCENE AGE
HAVERSTRAW, N. Y.

This partial section of Haverstraw brick clay, 30,000 years old, was deposited seasonally in fresh water as the ice of the last glaciation retreated northward. The space between pins represents a year. The lighter colored layers of fine sand are the summer deposits; the dark bands of clay are the winter layers

This calculation is based upon the present rate of denudation and delivery. It is most probable that the rate is much higher now than during many of the former geologic ages when the lands were less high, less extensive, and the seas more widespread. To account for these differences, J. W. Gregory (1921) recommends that the present estimates based upon sodium should be multiplied by five giving a total of 1,800,000,000 years as the age of the oceans.

The age of the earth based upon the thickness of the stratified formations is more difficult to apply since the average annual rate of deposition of sediments is not definitely known for the present or for past epochs of geologic time. A. Holmes, 1927, estimates the thickness of the sedimentary deposits of various ages as 529,000 feet or 100 miles. J. H. Bretz, 1926, on the basis of several estimates obtains an average rate of accumulation of one foot in 880 years. These figures give a total of 465,520,000 years as the amount of time required for the deposition of the sedimentary record.

This estimate does not include, however, the beds which were deposited in epicontinental seas, uplifted and subsequently removed by erosion, leaving only an erosion plane as a record of the events. Neither does it take into consideration those great gaps separating the five eras of geologic time when sedimentation was presumably confined to the margins of the continental platforms. Ocean waters now cover the margins of the continental platforms to a depth of 600 feet and embrace continental areas totaling 10,000,000 square miles. J. Barrell, 1917, notes that geologic processes, embracing erosion, sedimentation, and deformation recur in composite rhythms in which landscapes alternate with seascapes and geosynclinal areas of sedimentation with high mountains. The processes of sedimentation are complex and variable, defying rates of deposition. Areas of sedimentation alternate with scour and fill, the resulting product represents merely the balance between these two processes. In some areas sediments may not always have reached so far, in others they may have been carried

away to more distant spots, leaving small or large gaps in the horizontally disposed sediments known as disconformities. On the basis of these numerous deficiencies in the stratigraphic record it would seem that the above estimate of 465,520,000 years should be multiplied by a small figure such as 4, to account for the total time involved since sedimentation began, namely, 1,862,080,000 years ago.

Another line of evidence, which has yielded remarkable results as to the age of the earth is the radio-active method. It was first used in this connection by Boltwood of Yale in 1907. It is based upon the invariable rate of disintegration of the radioactive substances, such as uranium, thorium, radium and actinium, which possess high atomic weights and disintegrate with the continuous emanation of helium into substances of lower and lower atomic weights, terminating in lead. While chemists and physicists have analyzed but a comparatively small number of rocks of different ages containing radioactive minerals, the determinations so far made yield results which are in accord with the sequence of rocks as determined by geologists. The radioactive method affords age determinations which are more accurate than that produced by any other known method.

According to G. von Hevesy in *Science*, Nov. 21, 1930, single atoms of uranium and other radioactive substances explode. The number of particles exploding and decaying in unit time is strictly proportional to the number present. Thus where one atom of uranium out of 1,000,000,000,000 atoms, (or a mass weighing 1/40,000,000,000 of a gram) explodes and disintegrates every 5 days, 73.05 atoms disintegrate in like manner in the course of a year. If the mass and the number of atoms be 10 times as large, 10 atoms will decompose in five days. If the mass be 100 or 1000 times as large, 100 or 1000 atoms will decompose in the same time. Hence, whether the mass be 10, 100, or 1000 times larger, it disintegrates at the same rate.

Uranium disintegration is thus a strictly uniform process whose velocity has remained unchanged throughout geological time. Von Hevesy says that it is the nucleus which is involved in the decay, and nuclear processes proceed independently of temperature, pressure, and other external conditions. Hence, he asserts there is absolutely no reason to believe that the process has gone forward at any different rate than at present at any period in the earth's history.

To students of this subject it is a well-known fact that the disruption of a uranium atom is always accompanied by the radiation of an alpha-particle, which is a charged helium atom, or by the loss of a beta-particle, which is a free electron. The alpha-particles leave the atom with a velocity of 8800 miles per second and travel a distance of about 2.8 cm. in air and about 0.013 mm. in mica before they become powerless. The beautifully colored "pleochroic halos" seen in mica (biotite) under polarized light are produced by these alpha particles as they are emitted by the contained uranium and the decomposed products of uranium. The fact that the halos, corresponding to the various radioactive substances, have the same diameter, indicates that the rate of decay has remained the same throughout the ages. To apply the rate of uranium decay as a measure of time it is necessary as von Hevesy says to obtain (1) the total quantity of uranium that has decayed in some mineral since the solidification of the earth, and (2) the rate of that decay.

Accompanying the radiation of alpha-particles from uranium it is known that one atom of helium, an inert gas, rises from the decay of each atom of uranium. Although a small portion of this helium escapes, most of it collects in the uranium bearing rock, where its volume gives a

Photograph by Barnum Brown

STRATIFIED CRETACEOUS DINOSAUR BEDS, ALBERTA PROVINCE, CANADA

The man near the center of the picture stands on the contact between the marine Pierre beds below and the fresh-water Belly River dinosaur beds above. The contact denotes not only a change in the character of the sediments, but a lost interval of time occurring about 65 million years ago

measure of the age of the rock. Lord Rayleigh noted that one cubic centimeter of helium may be produced from one gram of uranium in 9,000,000 years. Since a small portion of the helium gradually escapes, this method gives but a minimum age. On this basis, age determinations of ancient rocks have been made to the amount of 570,000,000 years.

Uranium has an atomic weight of 238, helium 4. Hence, as the decay proceeds and helium is liberated, the products of the decay have atomic weights, 234, 230, 226, 222, 218, 214, 210 and 206. The atomic weight of a beta-particle is 1/1800, hence, when it is lost, the atomic weight is decreased by an insignificant amount.

The atomic weight 206, which is lead derived from uranium, is of special interest in radioactive determinations, since it is a solid product and does not disintegrate. It may be observed that 238 parts of uranium produce 206 parts of lead as 32 parts of helium are developed. Hence, from the known rate of the production of helium from uranium, A. Holmes, 1927, calculates that a million grams of uranium give rise to 1/7400 of a gram of lead every year. Holmes also presents formulæ for making age determinations from the various radioactive minerals. Thus after determinating the lead content of the uranium minerals it is possible to calculate what proportion of the uranium has decomposed since the mineral was formed.

In the *American Journal of Science* for March, 1927, A. Holmes and R. W. Lawson reviewed the methods of determining the radioactive disintegration of 18 samples and presented 22 determinations, the results of which have been incorporated in the left margin of the geological time scale on page 137. In the same journal, Aug., 1930, A. F. Kovarik described two additional analyses of ancient rocks, one for 1,465,000,000 years, the other for 1,852, 000,000 years. These have also been added to the chart.

The radioactive method, which is based upon the natural disintegration of uranium to lead, is of great importance for it enables us to determine the following interesting things about the earth:

1. The age of the oldest igneous rocks containing radioactive minerals, that is, the minimum age of the earth.
2. The date of various events in the later history of the earth.
3. The nature perhaps of various transformations in the gaseous and liquid stages of the earth's history.
4. The maximum age of the earth.

As to these various points it may be said that the oldest radioactive mineral so far determined is a specimen of Uraninite from Sinya Pala, Carelia, in northwestern U.S.S.R., and that its age is 1,852,000,000 years as determined by A. F. Kovarik, Sloane Laboratory, Yale University, August, 1930. Another specimen of the same mineral from Keystone, South Dakota, as determined by Prof. Kovarik, gave 1,465,000,000 years. It is probable that other specimens yielding an even greater age may be found and that the minimum age of the earth, that is, the formation of the crust, may be considered to have begun approximately 2,000,000,000 years ago.

The age determinations of various events in the later history of the earth have been entered in the geological time scale on page 137.

The third and fourth points are of special interest, since the early history of the earth is still obscure. According to von Hevesy, 1930, the uranium-lead method is not only of value in determining the lower limit of the age of the earth's materials, but of the chemical elements. As a chemist he considers that the transformation of uranium into lead had already progressed to a certain point while the earth's material was still gaseous. He asserts that this lead with atomic weight 206 did not remain isolated, but mixed with lead (208) formed by the decay of thorium and as a result common lead (207) was produced. He goes on to say that approximately half of our common lead was formed from uranium before the earth's materials had solidified. He cites F. W. Aston as having proved recently that ordinary lead is a mixture of uranium-lead and thorium lead. He considers that lead formed in uranium minerals has had no opportunity to mix with thorium lead and consequently it has remained fixed as uranium-lead. Thus the ratio of all the uranium to about half the common lead (plus the uranium-lead) present in the whole earth must give the age of the earth's material. His considerations give about 3000 million years as the upper limit of the age of the minerals; it is also the lower limit of the age of the earth's material. He draws a distinction between the few radioactive elements, which have altered according to accurately known laws during this long time, and the other elements which built up the earth's constituents and have undergone no change.

SECTION OF FORDHAM GNEISS, ARCHÆOZOIC AGE NEW YORK, N. Y.

The folded and contorted bands of light and dark colored minerals represent lines of segregation of the mineral matter, and folding when in a plastic state. It is typical of many Archæozoic rocks. Specimen from excavation, eastern abutment of Fort Washington bridge over Harlem River. Age problematical, perhaps 1800 million years

MUD FILLINGS OF "SUN CRACKS," SUPAI FORMATION

A specimen of lower Permian age that is some 215 million years old. It exhibits the same physical phenomenon as is found in the Hakatai shale specimen 935 million years old of middle Proterozoic age. From the Grand Cañon of Arizona. Lincoln Ellsworth Collection, 1930

The foregoing determinations have had to do with the crust of the earth. Since the earth's interior is inaccessible, the geochemist turns to the meteorites and assumes that the iron meteorites correspond to the core of the earth, and the stony meteorites to the more or less silicate-like material lying between the core and the crust.

F. Paneth of Berlin developed in 1926 the methods for determining the helium content of meteorites. He notes that the iron meteorites when heated to a red heat loose no trace of helium. According to von Hevesy, 1930, Paneth has found for the iron meteorites a maximum age of 2600 million years.

These data are significant. It lends support to the theory that the original materials of the earth and of meteorites may have come from a common celestial source. It also implies that the youthful earth, which grew presumably from the inner core outward by the addition of layers of planetoid and planetesimal matter, began its development 2,600,000,000 years ago. The oldest surface rock so far analyzed yields an age of 1,852,000,000 years. The difference in age between the oldest rock and the oldest meteorite is 748,000,000 years. May not this difference, or some 600,000,000 years, represent the time consumed in the upbuilding of the primeval earth?

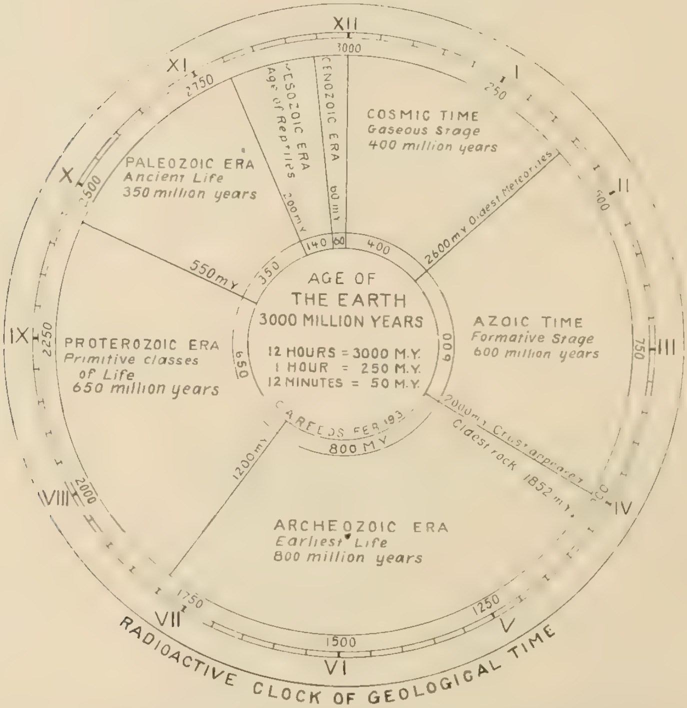
In conclusion it may be stated that these radioactive determinations are not only astounding, but remarkable. Al-

PROTEROZOIC RIPPLE MARKS AND "SUN CRACK" IMPRESSIONS

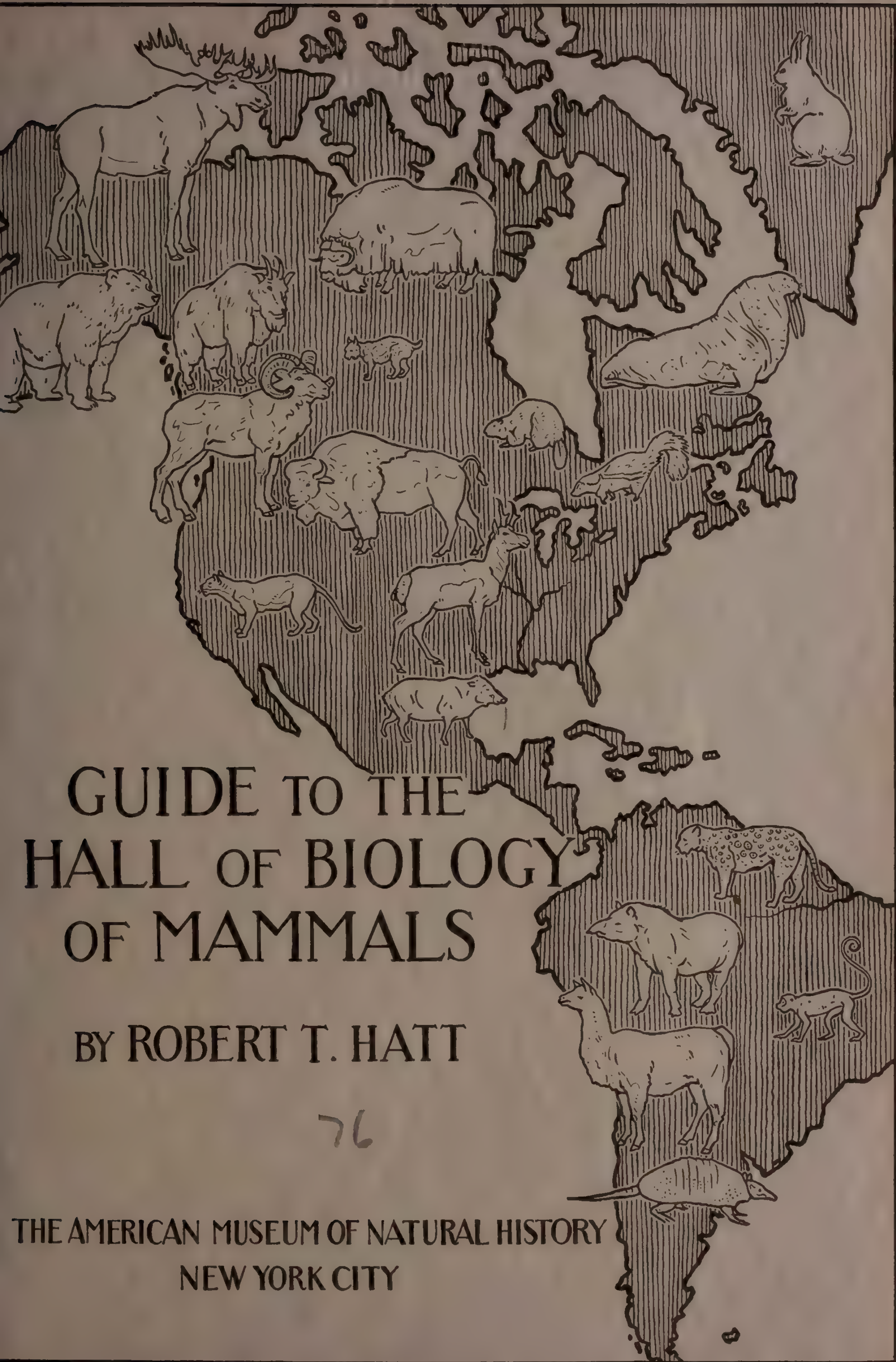
This slab of red Hakatai shale of middle Proterozoic age is some 935 million years old. It shows that the same physical phenomena were in force during the early eras of the earth's history as are in evidence today. Specimen from the Grand Cañon of Arizona. Lincoln Ellsworth Collection, 1931

though the method is still young the results are dependable. The method is based upon the natural rate of disintegration of the atoms of the few radioactive elements. This rate cannot be changed by any known human or physical agency. It is thus a reliable and thoroughly scientific method. When its application has been extended to numerous samples of radioactive rocks and minerals from all parts of the world, embracing rocks of all ages, then we shall know, in all probability, how old the earth is.

Upon the basis of knowledge for 1931, we may consider the crust of the earth to be 1,852,000,000 or about 2,000,000,000 years old; the inner core, 2,600,000,000 years old; and the upper limit of the minerals, or materials of the earth, as 3,000,000,000 years old, as noted below in the radioactive clock of geological time. The radioactive determinations and the oldest fossils indicate that primitive life was present on the earth one and one-half billion years ago; stone implements and human remains in Pliocene deposits imply that the human race was on the earth about one and one-half million years ago.



This clock face of 12 hours shows how 3000 million years may be allotted to seven stages in the geological history of the earth. The first and second stages representing the gaseous and formative eras respectively, are not shown on the preceding more detailed radioactive chart of geological time, page 137.



GUIDE TO THE HALL OF BIOLOGY OF MAMMALS

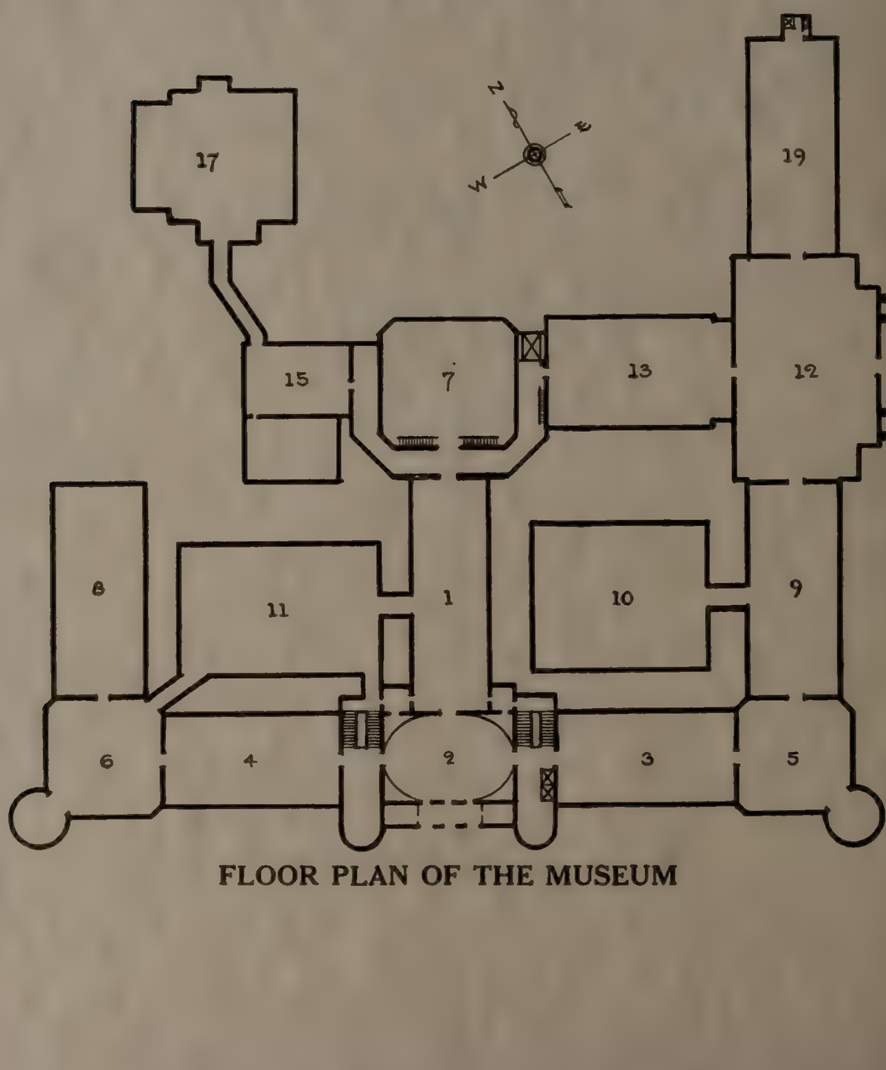
BY ROBERT T. HATT

76

THE AMERICAN MUSEUM OF NATURAL HISTORY
NEW YORK CITY

THE MAMMAL HALLS OF
THE AMERICAN MUSEUM OF NATURAL HISTORY

1. Hall of the Biology of Mammals. Third Floor, Sec. 3.
2. North American Mammals. Second Floor, Sec. 3.
3. South Asiatic Mammals. Second Floor, Sec. 9.
4. Marine Mammals. First Floor, Sec. 10.
5. North Asiatic Mammals. In Preparation.
6. African Mammals. In Preparation.
7. Primates. Third Floor, Sec. 2.
8. Mammal Photographs. Third Floor, Sec. 2.
9. Horses. Fourth Floor, Sec. 2 West
10. Fossil Mammals. Fourth Floor, Secs. 2 and 3.
11. Introduction to Anthropology. Third Floor, Sec. 4.



FLOOR PLAN OF THE MUSEUM

GUIDE TO THE HALL

OF

BIOLOGY OF MAMMALS

THE FAMILY TREE OF MAMMALS

GUIDE TO THE HALL OF

BIOLOGY OF MAMMALS

IN

THE AMERICAN MUSEUM
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By ROBERT T. HATT

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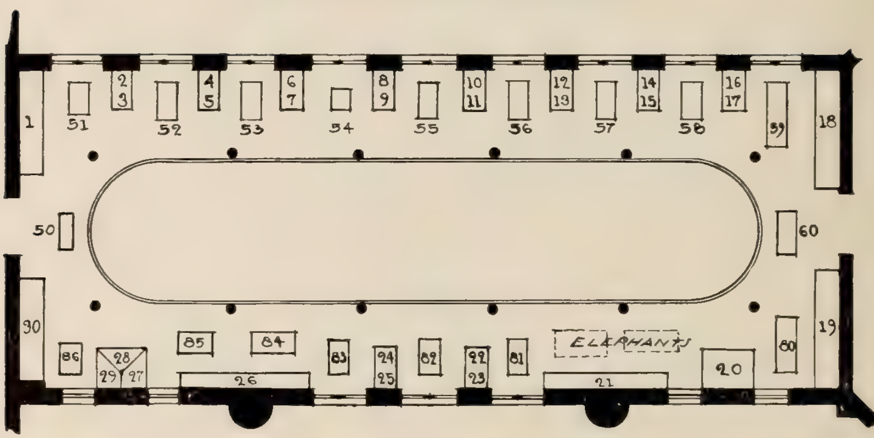
FLOOR PLAN OF THE HALL



The numbers are those which may be found marked on the cases. Reference to these cases is given in bold faced type in this Guide.

GUIDE TO THE HALL OF THE BIOLOGY OF MAMMALS

By ROBERT T. HATT

This booklet is intended primarily as a guide to the synoptic series of mammals and the exhibits of mammalian biology that constitute the "Hall of the Biology of Mammals." It is hoped, however, that enough information is contained within the covers to make its interest extend beyond the walls of this Museum and that it may serve to refresh the memory of the visitor whose stay at the Museum was all too brief.

The visitor will find it convenient to study the exhibits from left to right. Doing this he will view in approximate order of specialization the larger natural groups or ORDERS of mammals. The exhibits pertaining to general mammalian biology are not, because of the limitations of space, grouped in any systematic order, but by following this guide much of broad interest may be found in the Hall that might otherwise escape notice.

THE MAMMALS PLACE IN THE ANIMAL KINGDOM

The animal kingdom is composed of an infinite variety of species which may be divided into about twenty major groups or phyla whose interrelationships are obscured by the antiquity of their origin. Some of these are structurally very simple and are thus called primitive. Others are of extreme complexity. A world-famed exhibit of these phyla may be seen in Darwin Hall on the first floor of the Museum. The mammals clearly belong among the phylum Chordata of which the chief examples are the vertebrates or back-boned animals, a group which contains five classes, the fishes, amphibians, reptiles, birds and mammals. Since the Chordata are the most highly organized of the phyla, and the mammals the most highly organized of the chordates, it is customary to place them at the head of the animal kingdom as is done in the "Tree of Animal Life" illustrated in Case 2. It must, however, be borne in mind that every living animal is in its own way greatly specialized for its particular mode of life and that the terms "highest" and "most primitive" are only relative.

What is a Mammal?

A mammal may be defined as any species of animal in which the young are nourished for a time on milk, a secretion of specialized cutaneous glands. The mammals constitute a natural though widely diversified, group of the vertebrate or backboned animals. All, at some period in their existence, bear a coat of hair, though in some groups such as the whale and man, this is largely lost before birth. In contrast to lower classes of vertebrates (fishes, amphibians and reptiles) the mammals have a comparatively constant body temperature, which is different for different species but notably lower in the primitive group, the monotremes (**3**). The body temperature may rise above normal in disease or become considerably lowered in a state of hibernation. The adrenal glands appear to act as the thermostat which coordinates the various elements of control.

This high and constant body temperature is associated with a complicated heat regulating mechanism. Among the mammalian characters composing this complex is a muscular sheet, the diaphragm, which by rhythmic pumping movements furnishes a more constant air supply than is enjoyed by other vertebrates.

A richly glandular skin by controlling surface evaporation aids in regulating body temperature. The skin contains two main types of glands, the sudoriparous or sweat glands, and the sebaceous or oil glands. These latter are ordinarily associated with hair follicles, and their secretion aids in keeping hair in good condition. The sudoriparous glands control evaporation and eliminate waste. They are regionally differentiated to several uses. The lacteal or milk glands are specialized sweat glands.

Mammals all possess a four chambered heart which keeps the well oxygenated blood coming from the lungs completely separated from the poorly oxygenated blood entering the heart from the body circulation. This efficient arrangement occurs only among the birds and mammals.

The brain is proportionately larger in the mammals than in other vertebrates by reason of enlargement of the fore brain or cerebrum. It is this part of the brain which accounts for the greater intelligence of the mammals and which is proportionately larger in man than in most other animals.

The skulls of mammals have the brain case comparatively larger than the skulls of other vertebrates, except certain birds which is an accommodation to increased brain size. The roof of the skull is simplified

by the loss of a number of bones found in more primitive vertebrates. Similarly the mandible or lower jaw has had the number of bones reduced to one.

In mammals there has developed a secondary bony palate in the roof of the mouth. The skull is hinged on the vertebral column by a pair of condyles in contrast to the single condyle of reptiles.

Mammals have three minute bones in the inner ear which are not represented as such in other vertebrates. The history of these bones has,

THE BRAIN CAVITY OF A REPTILE SKULL

THE BRAIN CAVITY OF A MAMMAL SKULL

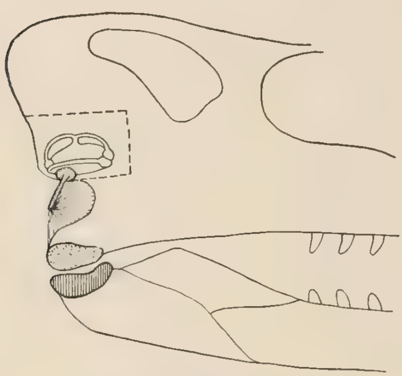
however, been traced. The *incus* or anvil bone is represented in other vertebrates as the *quadrate;* the *malleus* or hammer bone by the *articular* bone of the lower jaw. The *stapes* or stirrup bone occurs in fishes as the *hyomandibular,* and in other vertebrates as the *columella.*

The teeth of mammals are usually more highly differentiated than are those of more primitive vertebrates. Typically they are regionally differentiated from front to rear into incisors, canines, premolars and

molars. In such an animal as a monkey the incisors are used chiefly to cut off food, the canines for fighting, the premolars for further breaking up of food, and the molars for the final crushing. In various types of mammals the teeth are variously modified for special purposes. (**83**).

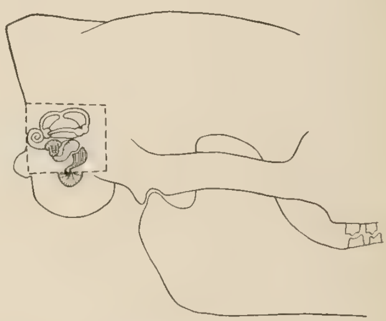
The mammals it is clear, evolved from the reptiles through a fossil group, the Theriomorpha, of which fossils are found in the Permian beds of South Africa. These animals possessed characters of the teeth and skeleton which are distinctly intermediate between those of reptiles and primitive mammals. The exhibits in Case 1 show the skulls of some Theriomorpha and many of the anatomical features by which the mammals and reptiles differ.

In mammals the vertebral column is typically well differentiated into five regions, the *cervical* or neck, the *thoracic* or rib bearing, the *lumbar*, the *sacral* which forms part of the pelvis, and the *caudal* or tail.



REPTILIAN

The forerunners of the mammalian ear ossicles as they lie in the reptile skull. The columella is indicated by horizontal hatching; the quadrate by stippling, the articular by vertical lines



MAMMALIAN

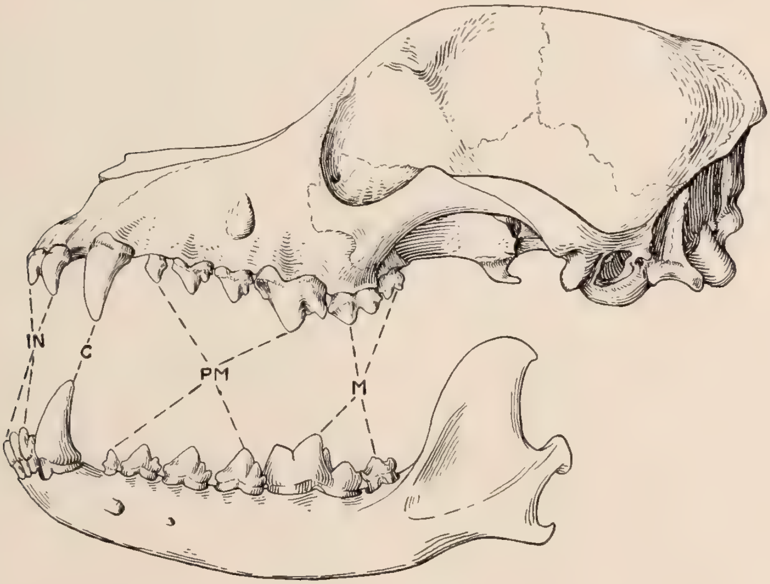
The ear ossicles of mammals. The stapes is the equivalent of the columella, the incus is derived from the quadrate, and the malleus from the articular

In almost all mammals there are seven cervical vertebræ. In the giraffe these are excessively elongated and in the whales excessively compressed. Only in the manatee (**21**) and a species of two-toed sloth (**16**) is the number reduced to six and only in the three-toed sloths is the number increased, here to nine.

The mammals develop bony ends or *epiphyses* on the limb bones (rare in reptiles) and on the vertebræ. It is between these epiphyses and

the shafts of the bones that growth in length takes place. When the sutures between them close growth stops (**23**).

The limbs of mammals are more efficiently constructed for rapid and sustained locomotion than are those of the other quadrupedal land vertebrates. The legs are brought more directly under the body, the length of the bones is usually increased and the joints tend more and more to limit motion to a fore and aft direction.



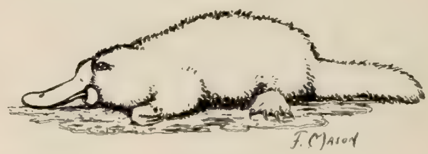
THE DENTITION OF A DOG

In generalized mammals the teeth are differentiated into incisors (IN), canines (C), premolars (PM), and molars (M)

THE LIVING ORDERS OF MAMMALS

MONOTREMATA

ECHIDNA

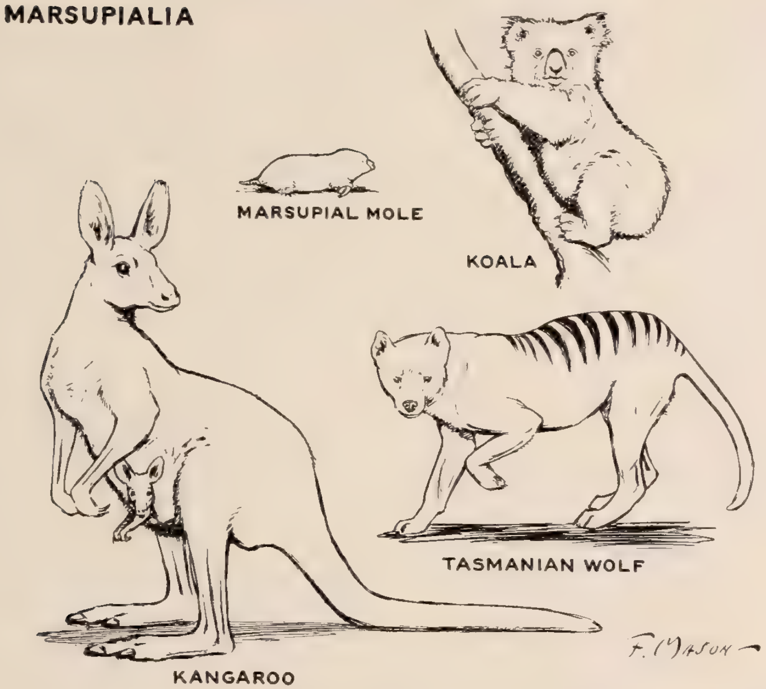


PLATYPUS

Monotremata. Egg laying mammals. Monotremes. (**3**). The monotremes are a small group of archaic mammals confined to the Australian region. They are considered the most primitive of all living mammals because they retain a number of reptilian characters among which are the reptile-like shoulder girdle, low body temperature, and egg laying habit. All higher animals and most primitive forms develop from fertilized eggs. In the monotremes, as in the birds, these eggs are surrounded with a shell and passed from the body shortly after fertilization. They are equipped with a large amount of yolk which serves as a food supply for the developing embryo. Among the higher mammals the fertilized egg contains little yolk and is retained within the body of the mother for the early period of development. The embryo here obtains nourishment from the maternal blood supply. The eggs of such mammals are never equipped with a shell.

The only representatives of the order Monotremata are the echidna or spiny anteater and the duck-billed platypus. These animals, though retaining primitive structures, are highly specialized to particular modes of life. The spines and toothlessness of Echidna are not primitive, nor are the poison secreting fighting spurs, the duck-like bill, webbed feet and horny teeth of the platypus.

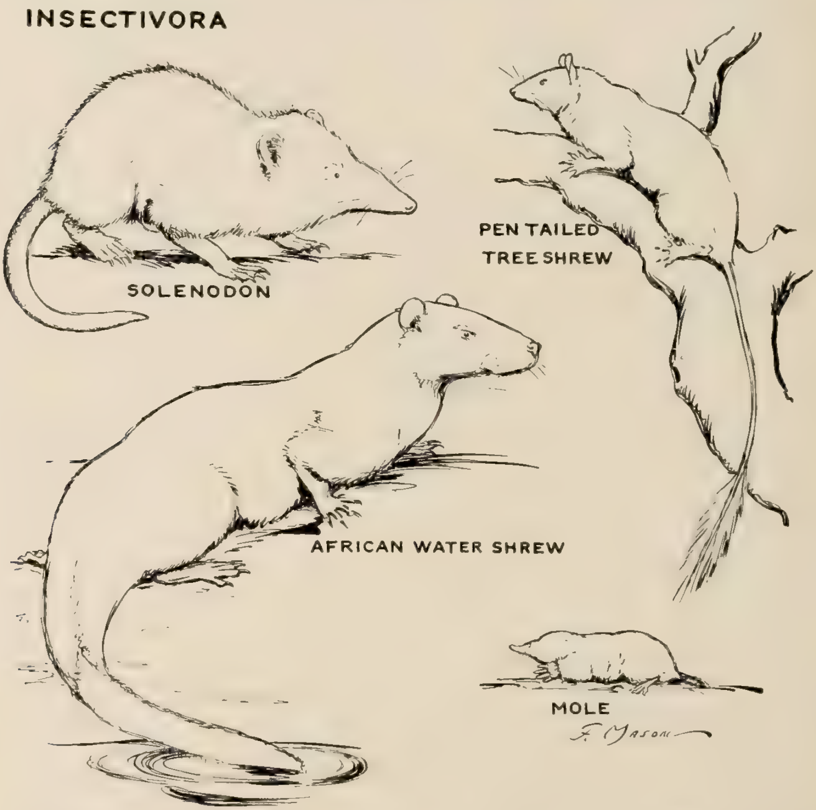
Marsupalia. Pouched mammals. (**4, 5, 52, 28, 29**). The marsupials retain more primitive characters in their structures than any order except the monotremes. They are an interesting and diversified group confined at present to the Australian region except for the opossums and Cœnolestidæ which occur in the Western Hemisphere. In the mammals of this Order the young are born at a very early stage of development and make their way into the pouch of their mother where they become fastened to nipples. In this pouch they are carried until they are able to shift for themselves. (See well-case opposite **4**).



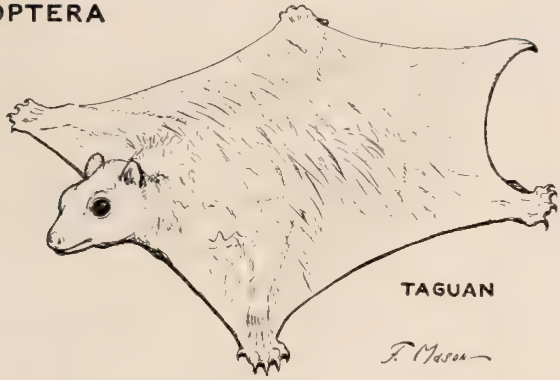
The marsupials have successfully invaded almost every realm of specialization except that of flying. Some leap, others climb, run, sail in the air, swim or dig like moles. Some eat flesh, some insects and others grass. One member of the Order, *Myrmecobius,* the marsupial anteater, possesses 54 to 56 teeth, the greatest number found in any land mammal. Marsupials are the only land mammals of Australia other than monotremes, man, bats, rats and mice, and the wild dog or dingo.

Insectivora. Insectivores. (**6, 7**). The insectivores are small primitive mammals, generally of flesh eating habits, that have survived the struggle for existence in part by the advantage of a high birth rate and the specialization to feeding habits in which few mammals compete with them. The members of the Order obtain their prey of beetles, grubs, worms and snails by burrowing in the earth, by hunting along its surface, by climbing trees, or by swimming. The muzzles of most of them are sharply pointed, a shape adapted to seeking out insects in the small cracks and holes in which they are apt to conceal themselves. Burrowing is best developed among the Talpidæ or moles, and the Chrysochloridæ or golden moles. These animals have modified the feet

into powerful digging members. An opposite extreme of locomotion is attained by the Macroscelididæ or jumping shrews which bound along in kangaroo fashion on their elongated rear legs. The Potomogalidæ or African water shrews have webbed feet and a powerful sculling tail. The tree shrews or Tupaidæ are remarkably like tree squirrels in habits and in appearance. They are of unusual interest to us in that they are probably descendants of the same stock from which the Primates (lemurs, monkeys, apes and men) originated. The hedgehogs or Erinaceidæ are spiny creatures of the old world, and externally resemble some members



of a Madagascar family of insectivores, the Tenrecidæ. The shrews or Soricidæ, whose soft velvety pelage is in extreme contrast to the spiny armour of the hedgehogs, contain among them the smallest mammals of the world. One other family, the Solenodontidæ is confined to a single genus of an ancient stock surviving because of its isolation from modern enemies on the two islands of Cuba and Haiti.



Dermoptera. Taguans. (**7**). The members of this Order are a strange group of oriental mammals which are equipped with large skin folds stretched between the legs and tail by which they glide through the air from tree to tree in the manner of our flying squirrels. One of the peculiarities of the taguans is the unique comb-like edge of the incisor teeth. Their molars are multi-cusped and suited to cutting up the leaves upon which they feed. Though having some characters of the insectivores, the Dermoptera are so entirely different from this group that they are usually placed in an order by themselves. It has been assumed that they are descendants of the same primitive stock as the bats, the tree shrews and the primates. The only English name for the taguans is "flying lemur" which is inappropriate inasmuch as they are not lemurs and do not fly.

Chiroptera. Bats. (**8, 9, 20**). The bats are the only flying mammals. They are not birds in any sense, but like other mammals give birth to living young which feed on milk. Their flying habits limit their modifications, but in spite of this they present a strong diversity, several hundred species havng been described. In size they range from the "flying foxes" of the Philippines (**20**) whose wings attain a five foot spread to tiny insect eating bats which with wings folded could rest on a silver dollar. Bats may be fruit eaters, insect eaters, blood-suckers (the vampires) or, in the case of an Indian bat, may feed on frogs, lizards, small birds, mice and even other bats. A bat of the West Indies has specialized

The comb-like incisor teeth of a taguan

CHIROPTERA

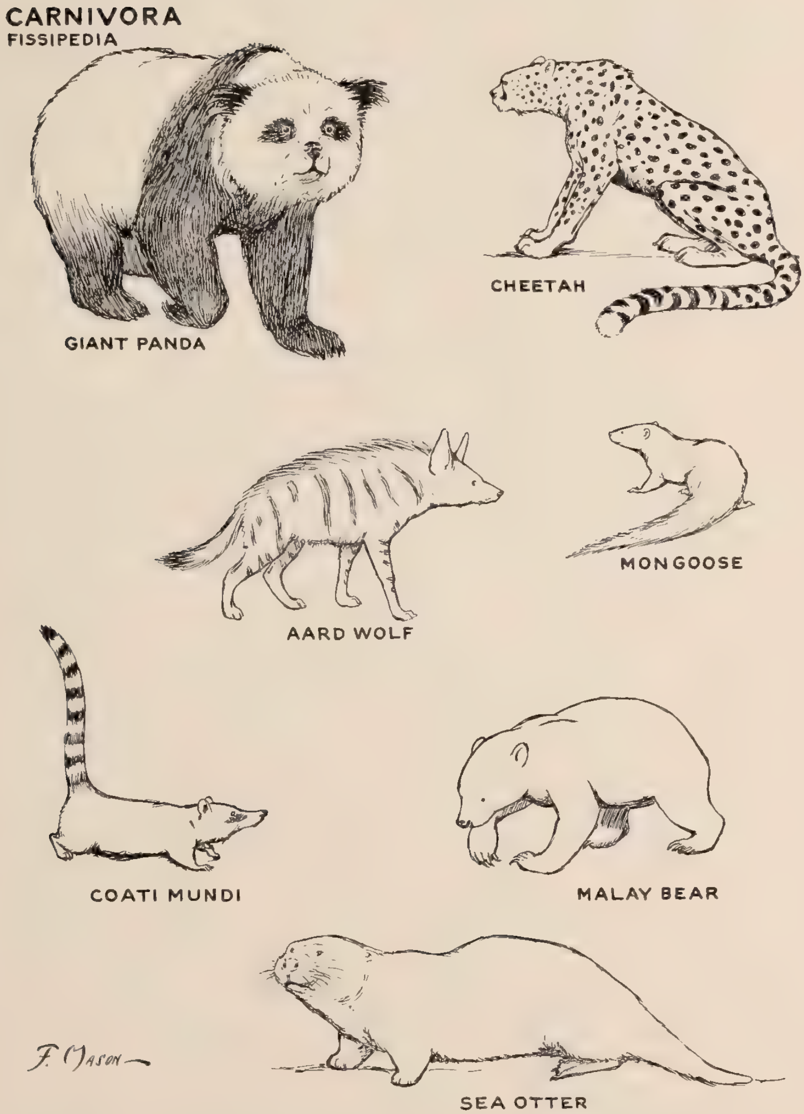
BAT

for fish-eating. Bats' teeth present many modifications of this primitive formula and range in number from 38 to 20.

Some bats are noteworthy for the peculiar skin structures developed on the face. These carry sensory nerve endings which are doubtless of great importance to them while flying in the dark. One group of bats bear suction cups on their wings, which enable them to cling to smooth surfaces.

Carnivora. Flesh eating mammals. (**10–13, 51, 53–56**). The carnivores fall naturally into two large groups that are by some consid-

The sensitive ears and skin folds of a leaf-nosed bat



ered separate orders. These are the Fissipedia or terrestrial carnivores, and the Pinnipedia or aquatic carnivores.

The Fissipedia are divided into a number of families which are of such universal interest that they may be separately characterized.

The Viverridæ, which are not represented in the New World, are

typified by the civets, genets and mongooses. One form, the fossa (*Cryptoprocta*, **53**) found in Madagascar is very cat-like. The mongoose of India is famous as a snake killer. From the civets comes a powerful musk used as the base for many perfumes.

The Hyænidæ include several African and Asiatic species which on occasion take living game but typically live off such carrion as they find at the kills of the big cats or other predators. A small relative of the hyænas, the aardwolf of Africa, subsists largely on white-ants and as other animals of similar food habits has a reduced dentition. This animal is placed in a family of its own, the Protelidæ.

The Felidæ or cats, lions, tigers, lynxes, leopards, cheetahs and others are lightly built carnivores with claws which (except in the cheetah) are retractible. They have short heads and, usually, long tails which, however, are never prehensile. The canine teeth of cats are unusually long and well suited to seizing and killing their victims. The cheek teeth are modified into sharp edged shears for slicing up the meat on which they feed. The most aberrant of the family is the cheetah or hunting leopard of Africa and Asia It is capable of great speed and is sometimes trained to hunt with men.

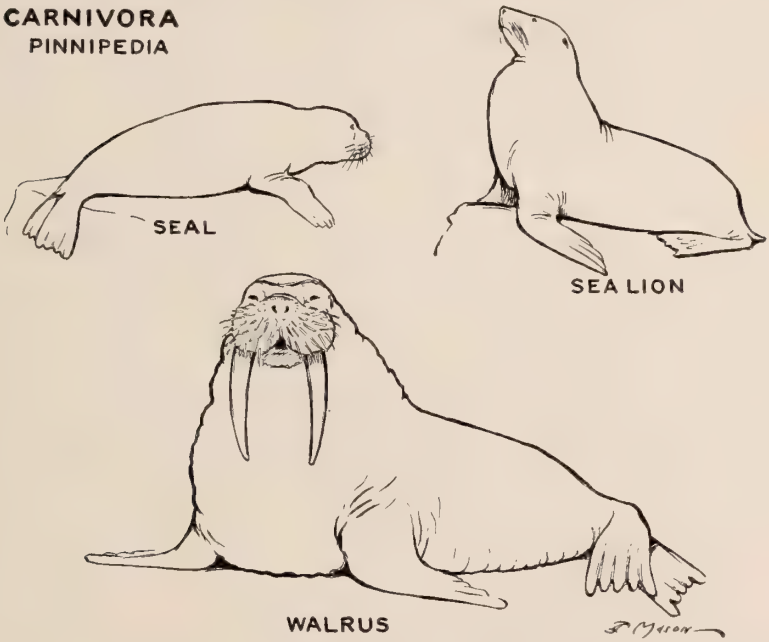
Amongst the Canidæ are wolves, jackals, dogs and foxes. They are all predatory creatures who usually obtain their prey by running it down rather than by using stealth. Among the more interesting species are the large eared fennec foxes, the short legged, web toed bush dog (*Icticyon*) of South America, and the hunting dogs of Africa, whose coat resembles that of a hyæna.

Exhibits of domestic dogs may be found in Section I on this floor, and also in the Darwin Hall on the first floor.

The Mustelidæ are differentiated as weasels, skunks, badgers, otters, wolverines and others. The family produces some of the finest furs, of which the ermine, sable and mink are well known examples. The most valuable skin individually is that of the sea otter, an animal that is as independent of land as a sea lion. Though once abundant in the North Pacific, this animal is now almost extinct as a result of exploitation. A single hide of this animal has been sold for as much as $1,400.

The Ursidæ or bears, are large massive animals with rudimentary tails and, ordinarily, shaggy fur. They are omnivorous in their feeding habits and their teeth, in consequence, are not highly specialized. Interesting members of this group are the polar bear, most aquatic of its family, the spectacled bear of the Andes, the little Malay bear which feeds mostly on fruits, and the giant brown bears of Alaska, the largest of living carnivores.

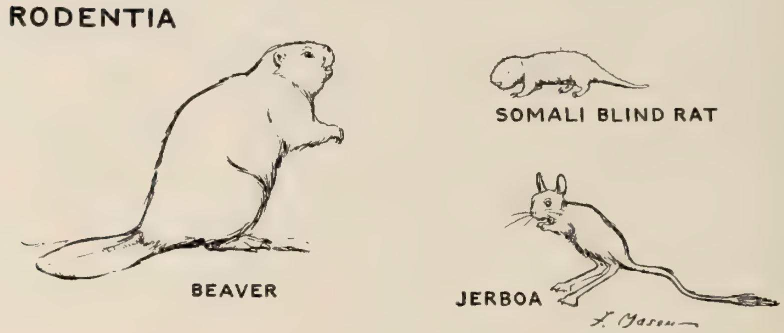
The Procyonidæ are American and Asiatic. The raccoon is here the most familiar member. The kinkajou, or honey bear (**54**), is a prehensile tailed species living in the American tropics, where one also finds the coati-mundi (**54**), a form with a long pig-like snout of good service in foraging along the forest floor. The panda, a handsome long-haired animal, brilliantly marked in red, black and white, lives in the Himalayas. In neighboring territory is found the giant panda (**56**) a rare bear-like



creature, said to feed largely on bamboo shoots. This unique animal, now placed in a family to itself (Aeluropidæ) combines characters of bears and procyonids.

The Pinnipedia or fin-footed carnivores are animals which have taken to aquatic life but which have not lost their dependence of land or ice fields for the birth of their young. The seals, sea lions and walrus which compose this suborder, represent well separated natural groups.

The true seals or Phocidæ are the most aquatic members of the order. Their hind feet are so bound together that they are unable to put them forward and can use them only for sculling action. The teeth which are sharp and often recurved are useful for seizing fish and other creatures upon which they prey, but are useless for cutting up the food.



The eared seals or sea lions (Otariidæ) have small external ears and like land mammals can place their hind feet forward for walking. The fur seals of the Pribilof Islands, of which good photographs are on exhibition in Sec. 2 on this floor, are commercially important members of this family. The California sea lion, often seen in circuses and on the stage, can be trained to do a remarkable series of tricks. The walruses (Odobænidæ) are somewhat intermediate between the eared seals and the earless seals. They are noteworthy chiefly for their long-upper canine teeth (tusks), which are used for digging up the clams on the ocean floor and for fighting. The flat and massive cheek teeth are adapted to breaking up the heavy shelled molluscs upon which they live. At present they survive only in the Arctic Seas.

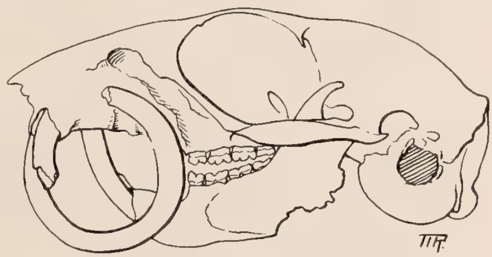
Rodentia. Gnawing animals. (**14, 15, 57**). The rodents are to the Mammalia what the insects are to all the animal kingdom, each eminently the most successful group in its field. Over 2000 species have been described, and these are spread all over the world with the exception of the Antarctic continent and a few remote Pacific islands inhabited only by bats. The rodents have adapted themselves to almost all types of life that other mammals have mastered. The great majority are however small inconspicuous rat-like creatures. The beaver, the muskrat and some others have taken to water life. The pocket gophers and mole rats have become almost as specialized for tunneling habits as have the moles. The jerboas, kangaroo rats and springhaas hop along on their rear feet as do the kangaroos. Some squirrels and other rodents are well adapted to tree living.

The diet of rodents does not vary to extremes. The dental equipment of all of them consists of four large chisel-like incisor teeth in front, a toothless diastema in the region of the lost canine, and a set of

grinding cheek teeth. The incisors consist of a strong band of enamel on the front surface backed by a core of dentine. The teeth working against each other wear away the soft dentine and leave cutting edges of enamel in front. As these teeth grow throughout life the rodent must gnaw to keep them in working order. When anything occurs to interrupt gnawing the teeth grow out in circles, which eventually prevent the animal from obtaining enough food to sustain life. Such deformed teeth may be seen in Case 67. To the rear of the gnawing teeth the lips fold in to form a curtain of skin which prevents splinters of wood, earth or other unwanted material which the animal is cutting, from entering the mouth.

The rodents are divided into many divergent groups. The most important of the sections of the Order are the following:

Lagomorpha. Hares, rabbits, pikas. These animals, which are so distinct from the other rodents, that it is sometimes questioned that they arose from the same stock, are characterized by the presence of two minute peg-like teeth immediately behind the large upper incisors.



RODENT INCISORS GROW THROUGHOUT LIFE
This squirrel suffered an accident to its mandible which resulted in faulty occlusion of its chiseling teeth. When these no longer wore against each other the teeth grew in circles

Rabbits and hares are known to all. The pikas are small relatives with short legs, short ears, and no tail. Usually, the pikas live among the rock slides of mountains, though they are occasionally found at low altitudes.

Sciuroidea. Squirrel tribe. This group of rodents contains such diverse types of animals as squirrels, woodchucks, kangaroo rats, pocket gophers and beavers.

Muroidea. Rat tribe. The most wide spread of the rodents are the Muroidea. While the best known types, the house rat and the house mouse are unattractive and are serious pests, numerous others, such as the European dormice are very pretty and interesting. By far the greater number of species are not enemies of man but are either neutral, or his benefactors.

Dipodoidea. Jerboa tribe. Though the long legged bipedal jerboas are the characteristic members of this sub-order, several other

TUBULIDENTATA

AARD VARK

families of rodents, among them the scaly tailed flying squirrels of Africa, the American sewellel, and the horned rodents of the Miocene age seem to belong here as distant relatives.

Hystricoidea. Porcupine tribe. The rat tribe is currently the most successful of the rodents, but the porcupine tribe seems to represent the culmination of rodent evolution inasmuch as its members are most highly adapted to the life of cutting and grinding vegetable matter. The porcupines are not the only members of the group. Others are guinea pigs, chinchillas, agoutis, and the largest of all rodents, the capybara (**57**). Though almost world-wide in distribution they are predominantly South American.

Tubulidentata. Aard varks. (**58**). The aard varks, (the name means "earth pig" and was applied to them by the Dutch colonists of South Africa) constitute the only instance of an order being represented by a single living genus. These animals feed almost exclusively on white ants or termites which they dig out with their powerful fore legs. The teeth of the aard-vark are simple cylinders of dentine which are traversed from base to crown by hundreds of minute passages.

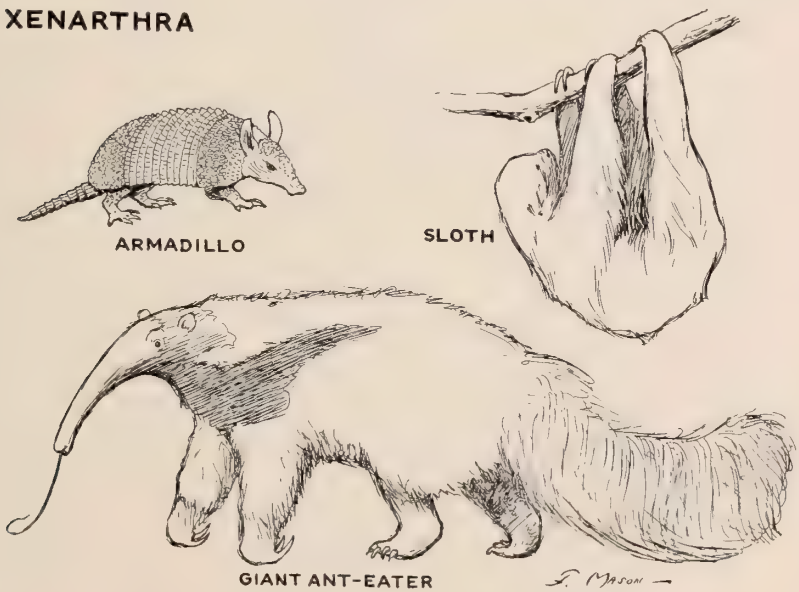
The principal foes of the aard-arks, other than arch-destroyer man, are the lions, the wart hog and the python. The lions feed upon the succulent aard varks and the latter two dispossess these termite eaters of their extensive underground retreats.

Aard varks, though known as fossils from Madagascar, Greece, India and Wyoming, are today confined to Africa. Their palaeontological record is, however, fragmentary, and offers little evidence as to their immediate antecedents. The evidence of comparative anatomy indicates that this Order arose from the fore-runners of the ungulates and that the early tube-toothed termite eaters followed an evolutionary course not dissimilar to that of the hyraxes.

Xenarthra. American edentates. (**16**, **50**). The anteaters, sloths and armadillos, though all related, externally have little in common. In spite of the fact that they are called edentates, only the anteaters are truly toothless.

The anteaters have long heads which accommodate the long sticky tongue with which they catch ants. The giant anteater or ant-bear (**50**) of South America, the largest of the order, attains a length of about five feet, much of which is in its great, bristly, brush-like tail. The tamandua (**16**) or arboreal anteater, is smaller and carries a prehensile tail. The two toed anteater is also prehensile tailed and arboreal, but is only as large as a squirrel.

The sloths are so modified for tree life that they habitually hang back downwards and walk with great difficulty on the ground. The feet and



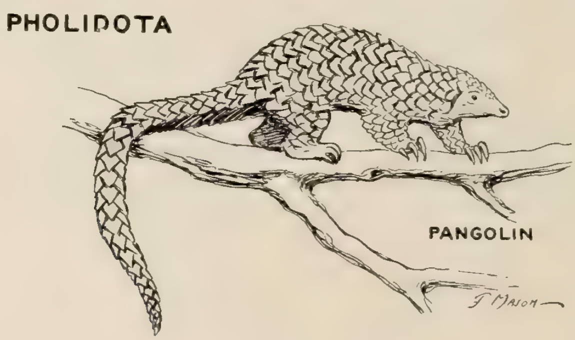
claws are modified into great hook s that circle the branches. The fur which is long and coarse, in one species harbors a growing green plant, (alga) which gives the animal a greenish tinge and makes it very inconspicuous up in the foliage.

Ground-living sloths existed in North and South America until recent times. Some of these grew to be as large as Indian elephants. Skeletons of these are on view in the Hall of the Age of Man.

The armadillos carry on their backs a jointed armour that contains bone. When attacked they roll up in this shelly armour and form an almost impregnable ball.

Only one species is found in the United States, the nine-banded armadillo. In South America lives a pygmy armadillo, the pichiciago (**16**) which dwells under ground, and carries on its rump a solid plate of bone firmly attached to the pelvis. With this it is said to block up its burrow. The largest armadillo attains a length of about three feet. A fossil related group, the Glyptodonts, sometimes attained a length of sixteen feet. Their great shells lying on the Pampas are said to have served as shelters to the first white visitors.

Pholidota. Scaly anteaters. (**17**). In Asia and Africa occur animals known as scaly anteaters, manids or pangolins. Externally they are all



much alike and bear a curious flexible coat of horny scales which probably represent fused bundles of hair or hair rudiments. The scaly coat of the pangolins serves them in many ways. Like the armadillos when attacked, they will curl up into a round ball that presents no soft parts to the enemy. When one of the tree climbing species falls it quickly curls up into a ball, and so efficient are the scales in absorbing shock that even a drop from a great height inflicts no injury. Feeding on ants as they do, pangolins are subject to the vicious attacks of swarming hoards of these biting stinging insects. Here again the smooth scales serve their wearer in good stead for a rapid quivering movement of the body sends the ants flying in all directions. The sharp edged scales of the tail are sometimes used against larger foes, and a hand caught between the scales of the tail and the body may be badly lacerated. Some of the pangolins are arboreal. In these forms the tail acts as a prop when they are climbing, and is so prehensile that it is used as a fifth arm.

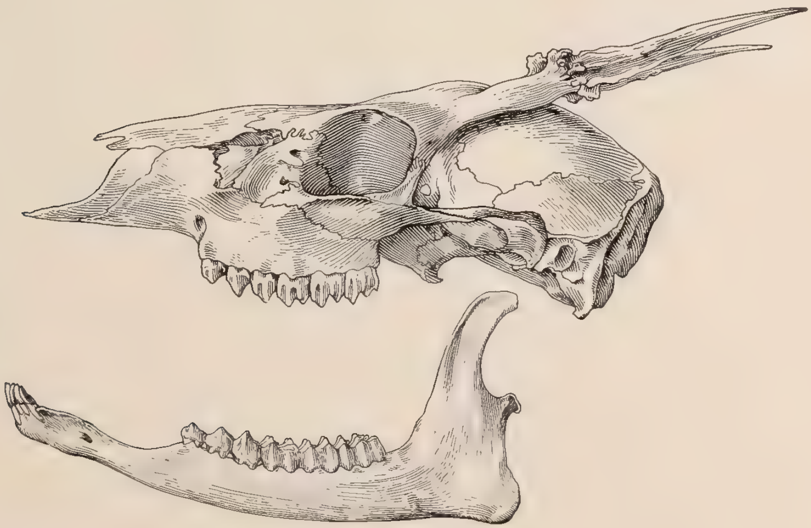
Artiodactyla. Even-toed hoofed animals. (**18, 60**). The artiodactyls are usually large animals, important to mankind in the region in which they inhabit. In the Order the main axis of the foot always passes between the third and fourth digits which are capped with hoofs. The following families constitute the group:

The Suidæ and their close relatives the Tayassuidæ are the pigs and the peccaries which may be identified by their flat-ended snouts and short tails. The diet of all of them is omnivorous.

The Hippopotamidæ are almost hairless, thick skinned aquatic vegetarians. The only living forms are the giant hippopotamus, widespread in Africa, and the pygmy hippopotamus of Liberia. Though these animals secrete a carmine colored fluid from the sweat glands they do not sweat blood as is commonly supposed.

The Tragulidæ or chevrotains (sometimes called mouse deer) are diminutive creatures living in southern Asia and West Africa. They are somewhat intermediate between pigs and deer. Their feet are pig-like, their stomachs have three divisions and the upper jaw bears long saber-like canine teeth.

The Camelidæ are two-toed artiodactyls with a long prehensile upper lip, long necks and legs. They all have thick, long hair which is extensively used for wool. The feet are protected by soft pads of skin.



The deer skull typifies the ruminants in which group there are no upper incisors to oppose those in the mandible

ARTIODACTYLA

WART HOG

HIPPOPOTAMUS

DEER

IBEX

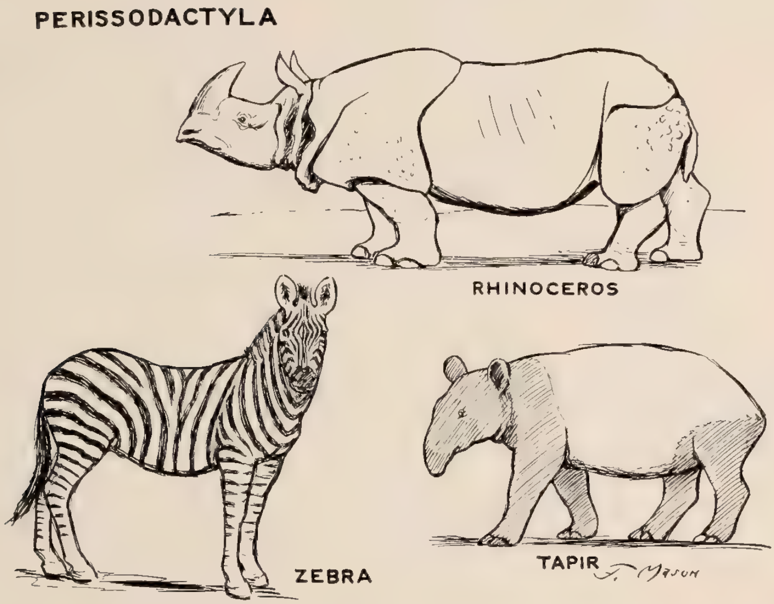
PRONG HORN

CHEVROTAIN

GIRAFFE

BACTRIAN CAMEL

F. MASON



The two species of camel are domesticated. The one-humped species ranges from North Africa to Central Asia. The two-humped or bactrian camel is exclusively Asiatic. In South America the llamas and several allied animals inhabit chiefly the Andean region where two of them, the llamas and vicunia are used as beasts of burden.

The Cervidæ, a family composed of the deer, the moose, reindeer and their allies, are typically species which develop bony antlers which are shed annually. In the caribou and reindeer, both sexes bear antlers, but in other Cervidæ the males only have these fighting weapons. Two aberrant forms, the musk deer and water deer do not have antlers but are equipped with fighting tusks.

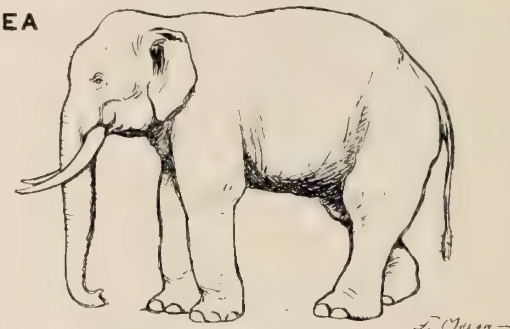
A wide variety of the deer of the world is shown in the Hall of Asiatic Mammals and the Hall of North American Mammals.

The Giraffidæ have skin covered antlers on the skulls. In the okapi, a little known animal of the Congo, these occur on the male only. In the giraffes they are found on both sexes.

The Antilocapridæ contains only the American pronghorn, the only animal which has branched hollow horns, and the only hollow horned mammal in which the horns are periodically shed.

The Bovidæ, a family including the oxen, antelopes, sheep and goats, are the hollow horned ruminants whose horns are not periodically shed.

PROBOSCIDEA



INDIAN ELEPHANT

These horns are in most species present in both sexes, though they are larger in the male. As in the Giraffidæ and Cervidæ, teeth are absent in the front of the upper jaw. The stomach, as in other animals which "chew the cud" is a complicated organ with four compartments, and the intestines are extremely long. This sort of digestive apparatus enables the possessor to get the most out of the flesh-making constituents of the vegetation.

Perissodactyla. Odd-toed ungulates. (**19, 59, 80**). The Perissodactyla, or tapirs, rhinoceroses and horses, are hoofed animals in which the central axis of the foot passes through the third digit which is always large and symmetrically shaped. In the Equidæ, or horses and zebras, this is the only digit left. The tapirs have four toes on the front feet and three on the rear. Among the rhinoceroses there are three toes on each foot.

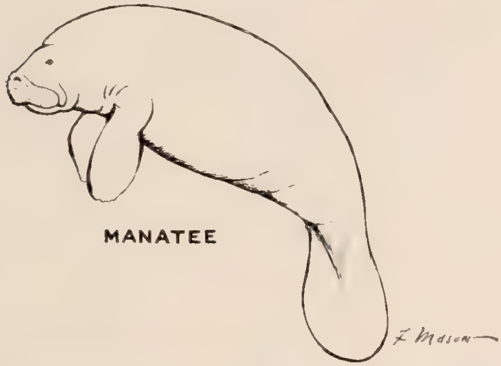
The tapirs, horses and rhinoceroses, though now most diverse, were in Eocene time very much alike.

Proboscidea Elephants. (**19**). The African and Indian elephants are the largest land living mammals, but they do not compare in bulk to the whales. Their exceptional tusks, trunk and many other character-

HYRACOIDEA

HYRAX

SIRENIA



MANATEE

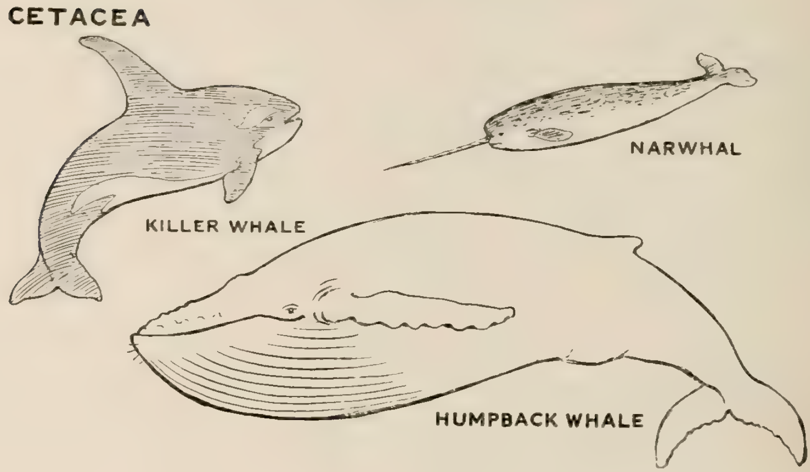
istics set them widely apart from all other mammals. The trunk, which has evolved from a shorter proboscis such as that of the tapirs, is the elephant's indispensable possession. With it he can pick up anything from a peanut to a heavy log. It serves him when he raises water for drinking, dusts or fans himself.

The evolution of the elephant is well illustrated by an extensive series of fossil elephants which may be seen on the fourth floor.

Hyracoidea. Hyraxes. (**19**). These small rabbit-like animals are, strange though it may seem more closely related to the elephants than to any other existing mammals. On their toes are small rounded hoofs, and on the soles are singular suction pads which give the hyraxes the power to climb trees and rocky surfaces. Their range covers most of Africa and Arabia. It is these animals that are called conies in the Bible.

Sirenia. Sea cows, manatees, dugongs. (**21**). The Sirenia are naked-skinned aquatic animals that, like the whales have lost their rear limbs and have developed a horizontal fleshy paddle on the end of the tail. Their bones especially in the manatee, are dense and heavy a conditon suited to their bottom feeding habits. In contrast to other mammals, their vertebræ lack epiphyses. The existing species all have teeth, but the rhytina had in their place heavy horny pads. The Sirenia are today inhabitants of warm quiet seas and tropical rivers, but the rhytina, which was exterminated by man less than two hundred years ago, lived among the Aleutian Islands.

It is probable that the myth of the mermaids had origin in distant glimpses which sailors had of these animals. With their heads out of water, and sea weed streaming from their mouths, or with a young one held up to the breast, the animals could easily give the illusion of being half human.



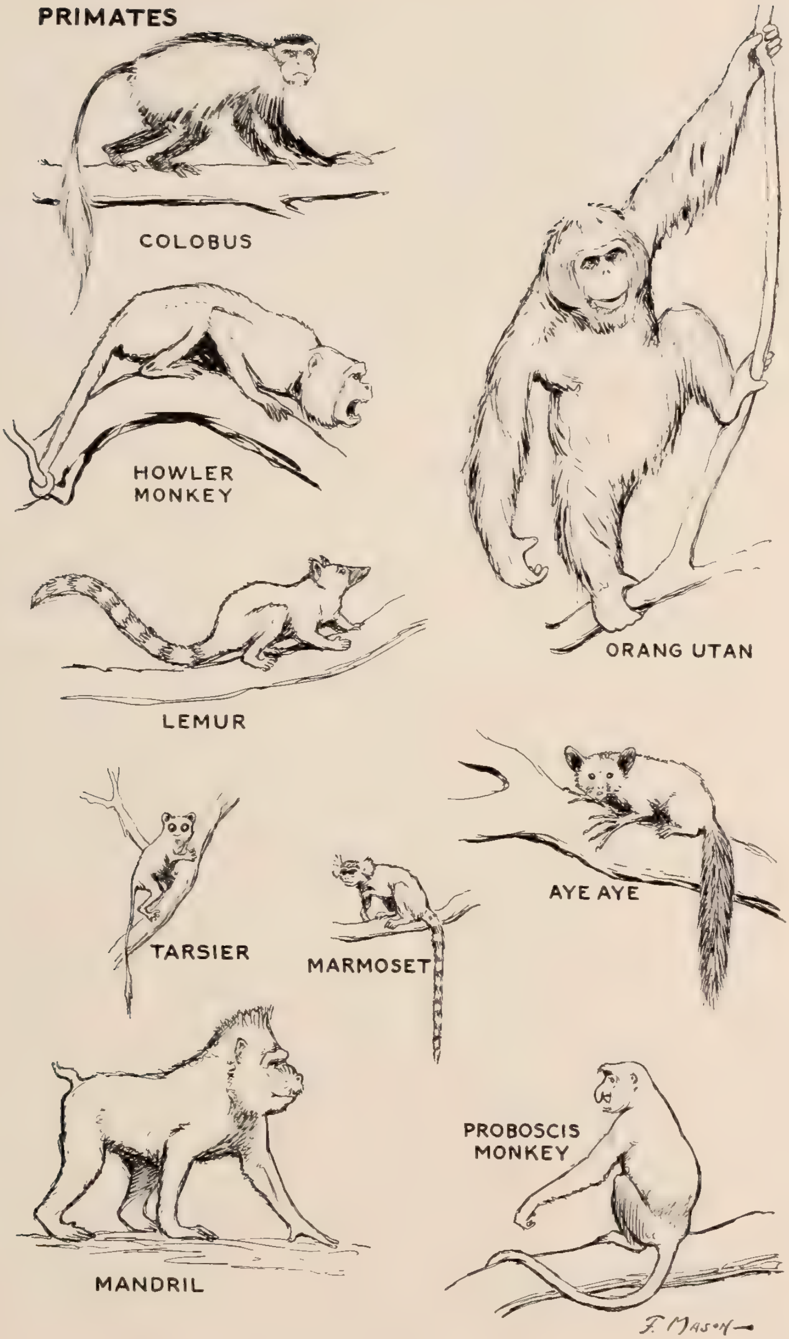
Cetacea. Whales, porpoises, dolphins. (**26**). The Cetacea are exclusively aquatic mammals which have completely lost their rear limbs, but which in some forms retain a small pair of bony rods deeply imbedded in the flesh that from muscular relations are recognized as the ischia of the pelvic girdle. The tail bears a pair of horizontal flukes that are without bony support, but which probably do all the work of propelling. Unlike the fishes, the whales breathe air into the lungs and do not possess gills. The "spouting" of certain species of whales is due to the condensation of water vapor leaving the lungs and striking the cold air. As other mammals, the whales are warm blooded, their young are born alive and are nourished on milk. The few hairs of the adults are found about the head.

Among the Cetacea are the largest mammals that have ever lived. The longest specimen ever measured was a blue whale of one hundred and three feet.

Primates. Lemurs, monkeys, apes and men. (**30**). The Primates are, on the whole, a primitive group, but certain specialized forms occur among them. Within the Order the orbit of the eye is protected by a ring of bone or is completely walled off.

Most Primates live an active life in the trees and this environment has left an indelible stamp on the whole group. All four feet are more or less hand-like, the thumb and great toe being set off at an angle to the others so that the feet are able to grasp limbs quickly and firmly. The feet of man are modified for terrestrial existence and the great toe is

PRIMATES


COLOBUS
HOWLER MONKEY
ORANG UTAN
LEMUR
AYE AYE
TARSIER
MARMOSET
MANDRIL
PROBOSCIS MONKEY
F. MASON

held parallel to the others, but there are still vestiges of the muscles that in our ancestors made this great toe an efficient grasping organ

The brain also reflects the arboreal life of the Primates. Centers of alertness, of intelligence and sight are large, while the brain center connected with smell is poorly developed.

The Lemuridæ are the most primitive members of the Order, the less modified of them have long fox-like skulls, and long tails and are arboreal in their habits. Though found chiefly in Madagascar, specialized forms such as the pottos and galagos, (bush babies) are found in Africa, while others, the lorises, occur in southern Asia. As fossils the lemurs are known from America and Europe as well as from the lands they now inhabit.

The most remarkable of the lemurs is the aye aye (*Daubentonia*) whose rodent-like incisor teeth are used to tear open the tunnels of wood-inhabiting insects, and whose third finger is transformed into a long thin searching probe for extracting the grubs upon which it feeds.

Most aberrant of the primates, possibly excepting man, is the tarsius (*Tarsius spectrum*) which has the hind feet extraordinarily elongated and possesses eyes that are so large that they very nearly touch in the middle. It is also noteworthy for its ability to turn its head in so great an arc that it is able to look directly backwards without twisting its body.

The monkeys of the New World are easily separated from those of the Old World by the character of their noses. In the former group (Platyrrhines) the nostrils are broadly separated, while in the Old World monkeys (Catarrhines) the nostrils, as in men, are close together. Other characters which are chiefly internal also separate the groups.

The New World monkeys may be divided into two families, the Hapalidæ and the Cebidæ. The Hapalidæ or marmosets are small creatures with non-prehensile tails and thumbs which are nonopposable and which, except on the great toe, bear claws instead of nails. The Cebidæ are South and Central American monkeys which usually have prehensile tails. The most familiar are the little capuchin monkeys (*Cebus*) which are common objects in zoological parks. The male howling monkeys possess enormous bony throat pouches which give their voices such tremendous power, that their calls may be heard for two miles. The spider monkeys are species with very long arms, legs and tails. The night monkeys are forms with large eyes that aid in the nocturnal wanderings.

The Old World monkeys (Cercopithecidæ) are most typically represented by the macaques of Asia and the members of the genus *Cercopithecus* of Africa. These animals have ischial callosities and, occasionally, cheek pouches, but never have prehensile tails. Specialized forms of interest are the baboons, dog-like semiterrestrial forms with long faces, powerful bodies and, usually, bad tempers. The mandril of West Africa is the most colorful of all mammals. The Abyssinian colobus monkeys are strikingly furred in black and white. It is the long hair of these animals that is sometimes used for trimming of women's wraps. A group of these monkeys may be seen at the entrance to the Primate Hall. The proboscis monkeys of Borneo are leaf eaters with enormous abdomens. Their name is given for the noses of the males which are very long and pendulous. A rare Asiatic primate, the snub nosed or golden monkey has a short nose turned up at the tip.

The remaining group of sub-human primates, the Anthropoid apes (Pongidæ) contains but five genera, the gibbon (*Hylobates*), the closely related siamang (*Symphalangus*), the orang utan (*Pongo*), the chimpanzee (*Pan*) and the gorilla (*Gorilla*). As man is so closely related to these animals some authors include him in the family, but usually he is placed in one apart, the Hominidæ, characterized by unusual enlargement of the forebrain, and upright posture.

The gibbons and siamang are extremely arboreal types whose hands almost touch the ground when the animal is standing upright. Both genera live in the Malayan countries. The orang utan is a large, tree living, red-haired ape inhabiting Borneo and Sumatra. Chimpanzees and gorillas are closely related forms living in the forested regions of central Africa. The gorilla attains the greatest bulk of any primate. Though features of advanced age mask the similarity, gorilla and man are much alike and probably arose from the same primate stocks in Miocene time.

The visitor who wishes a more comprehensive view of the primates than is obtainable in this Hall may see a wide variety of representative types mounted and as skeletons in the adjoining Primate Hall. One interested in the record of fossil man would do well to visit the Hall of the Age of Man on the fourth floor.

MAMMALIAN BIOLOGY ILLUSTRATED IN THIS HALL

Though the greater part of this Hall is devoted to a systematic arrangement of the principal orders and families of mammals, it has also been attempted to illustrate a few of the more interesting aspects of mammalian biology.

The synoptic series of mammals illustrates to some extent the range of variation in adaptation to environment. In addition to this there are special exhibits which illustrate particular phases of the adaptive radiation of mammals.

ADAPTIVE RADIATION IN THE LOCOMOTOR APPARATUS

As animals of different ancestry have adopted similar modes of life they have tended to become similar in some of their features. Thus the whales and the manatees, mammals of totally different ancestry have both lost the greater part of their hairy coats, rear limbs and external ears, while both have modified the fore limbs into paddles and developed a horizontal fluke on the tail. There are innumerable instances in the animal kingdom of animals that look alike externally and yet are fundamentally different Several examples of this principle have been assembled in case 29. This approximation of dissimilar stocks is called *convergence.*

Aquatic Adaptations

The most specialized aquatic mammals are the Cetacea, or whales and porpoises, illustrated by the life-sized model of a sulphur-bottom whale suspended from the ceiling, the porpoises above the cases, and by scale models of other whales in Case 26. Other less modified aquatic animals illustrated are the seals and sea lions (**12**, **28**), the otter (**29**), the Congo water shrew (**6**, **29**), the desman, an European insectivore (**29**), the manatees and dugongs (**21**), muskrat (**29**) beaver, and platypus (**3**). Specialization for aquatic life results in modification for warmth in cold water which may be a thick layer of fat, as in whales where it is known as blubber, or the development of a thick water resisting fur, as in the muskrat. Food habits become specialized too, and the food catching structures are modified accordingly. One group of whales has developed horny plates of baleen (**26**) for straining minute animal life from the water. The teeth of the seals are specialized for catching fish, while the teeth of the walrus are heavy and plate-like for cracking clams. The rhytina (**21**) which fed on soft marine plants, had lost all of its teeth.

The locomotor apparatus is highly modified. The fore limbs may become paddles (Sirenia, Pinnipedia) and the hind feet may be bound together (seals) or entirely lost (Cetacea, Sirenia). In less specialized aquatic animals the toes become webbed. The tail is often an important propulsive organ (Cetacea, *Potomogale*). The bones of the manatee are very dense and heavy to enable it to remain submerged while feeding.

Skeletons of aquatic animals are displayed in Cases 6, 21, 22, 26. Skeletons of the larger whales are on view in the Hall of Ocean Life.

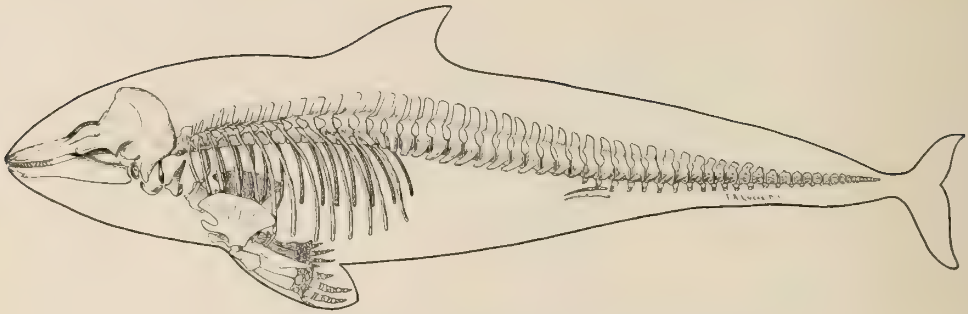
Fossorial or Digging Adaptations

In the soil lies a rich food supply of plants and animals on which many mammals are partially or totally dependent for sustenance. Several groups have become so specialized for this type of feeding that they spend virtually their whole lives in tunnels which they make under the earth. This has resulted in the reduction or total loss of their visual powers which are of no use in their dark world. The fore feet are always shortened and enlarged for digging, while the muscles that operate them are powerful. The neck becomes shortened, and the tail, which can be of little use, is usually short. The best representatives of this type of specialization are the marsupial-mole (*Notoryctes*, **29**, **4**), the insectivorous garden moles and golden moles (**29**, **6**), the mole-rats (**14**) and sand rats (**15**) of the Old World, and the pocket gophers (**14**) of the New World.

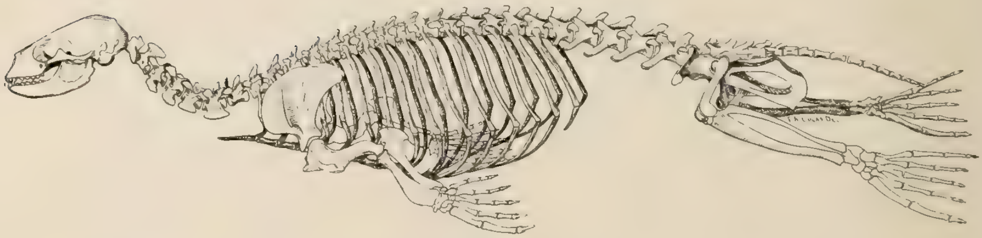
Scansorial or Climbing Adaptations

Many animals are capable of climbing trees, but for obvious reasons large animals are not successful in this life. Animals take to the trees for food to escape enemies, and to build their nests. It would be difficult to name the most successful of tree-living creatures, but without question the sloths are the most highly specialized.

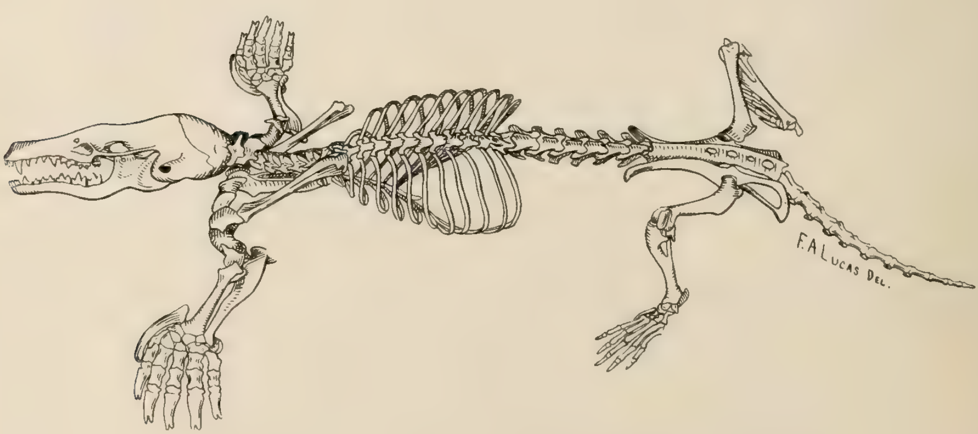
Tree living requires modification of the hands and feet or claws that enable an animal to catch hold of the bark or encircle the limbs. Cats, squirrels and many others have sharp claws for catching in the bark. The sloths (**16**) have sickle-shaped fingers and claws which enable their bearers to hang below the branches. Tree living primates (**30**) phalangers (**52**) and opossums (**4**) have strongly divergent great toes that aid the animal in grasping. Some primates such as the spider monkey and gibbon, which are capable of rapid swinging (brachiating) passage through the trees, have the thumb reduced so that it is not in the way when the hand takes hold of a limb in rapid progress. The tree hyrax, (**19**) tarsius (**30**) and a bat (*Thyroptera*) are equipped with suction



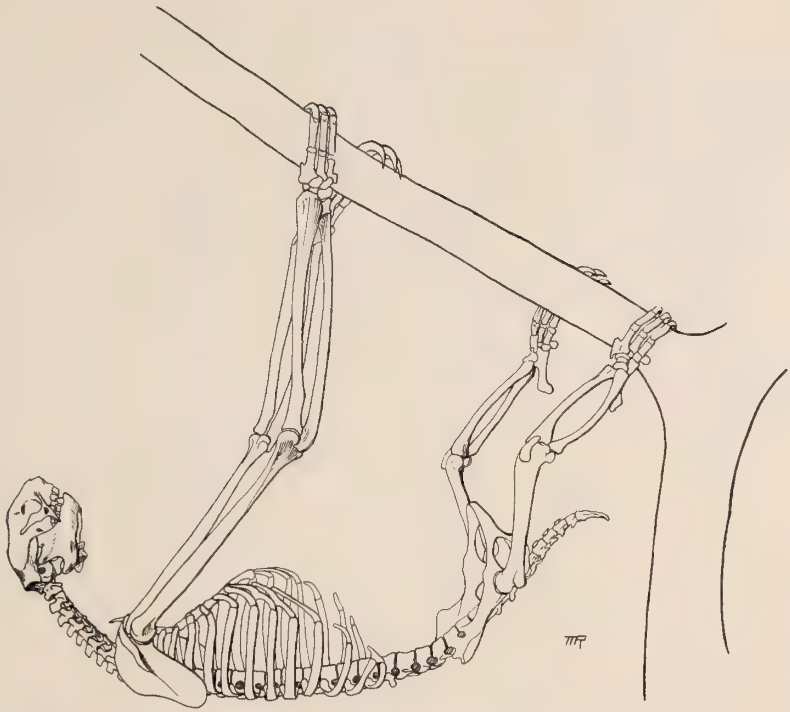
The skeleton of a porpoise, highly specialized for an aquatic life



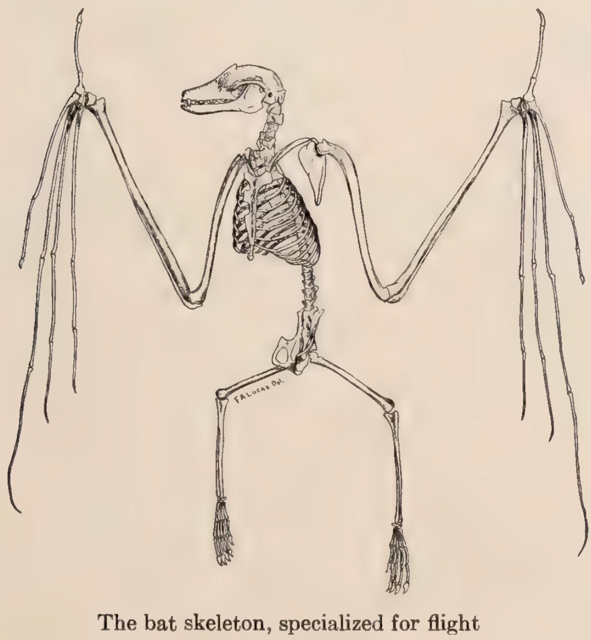
The skeleton of a seal, specialized for an aquatic life but retaining many primitive characters of a land living ancestor



The skeleton of a mole, modified for burrowing in the earth



The sloth skeleton adapted to an inverted posture



The bat skeleton, specialized for flight

devices that enable them to cling to smooth surfaces. In the hyrax the middle of the fleshy foot pad may be drawn up to create a vacuum, by which means they are said to ascend vertical tree trunks.

Many animals in many orders have developed prehensile tails that act as a fifth suspensive organ. This is found in the opossum (**4**) and phalangers (**52**), the kinkajou (**54**), the tree porcupine, the arboreal manises (**17**), the tamandua (**16**), and some New World monkeys (**30**).

Some of the animals have strong tails with which they may prop themselves against the tree when ascending. The climbing pangolins and the scaly-tailed flying squirrels (**14, 29**) have not only this adaptation, but in addition possess horny scales which effectively prevent the tail from slipping.

Volant or Flying Adaptations

Only the bats among mammals have developed into true flyers. Their evolution was so remote and the fossil record so poor that we do not know the steps by which this specialization arose. In artful dodging they are not surpassed by the birds, but when not in flight they are very awkward.

In the bats the anatomical specializations for flying have been the tremendous lengthening of the fore arms (**8, 9, 20, 22**), and the second to the fifth fingers, the great enlargement of the chest muscles which operate the wings, and the growth of the skin to form a web stretching between the fingers and the rear legs. In many of the species the skin extends between the legs and out to the tip of the tail.

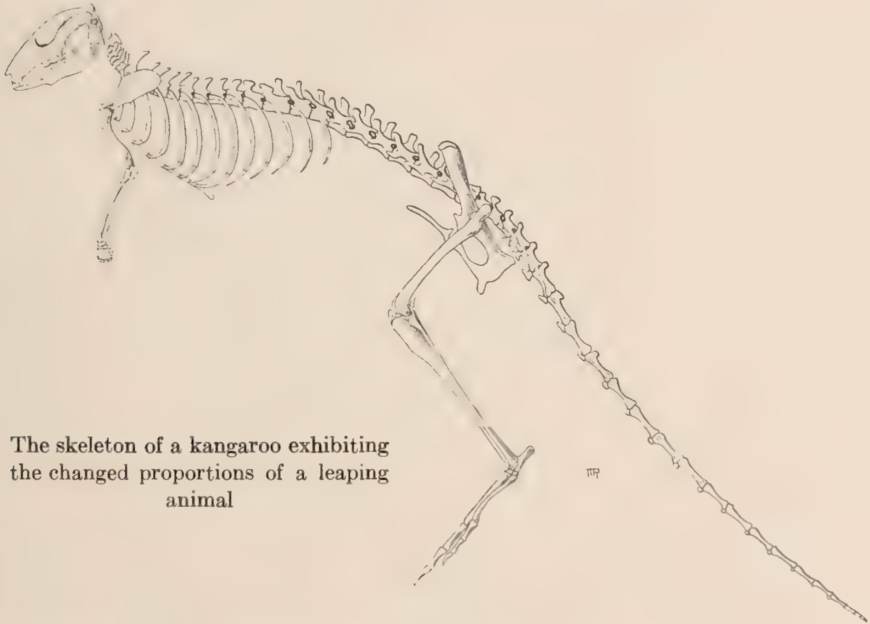
Gliding Adaptations

Though only the bats among mammals have mastered true flight, other groups have developed membranes between the fore and hind legs that enable them to glide through the air from a high point to a lower one. This modification has given all of them a superficial resemblance. No one closely acquainted with the animals or seeing them divested of their skins would, however, think of them as related. Here again is illustrated the principle of convergence. Three unrelated types, the flying phalanger, the flying squirrel and the scaly tailed flying squirrel are exhibited in Case 29. Another, the taguan is to be seen in Case 28.

Cursorial or Running Adaptations

Cursorial adaptation implies ability to move not only rapidly but to sustain high speed for a long distance. To do this the limbs must be long and straight (**81, 22**) the joints must have the movements restricted

chiefly to the fore and aft plane, and the fore and hind limbs must both be strongly developed. The adaptation is best if the point of contact with the ground is limited. The horses (**19**) are possibly the most perfect examples of this type of adaptation, though many of the artiodactyls (**18**, **60**), particularly antelopes, are excellent runners. In the marsupials the Tasmanian "wolf" (**52**), is the best cursorial type while among the carnivores, the cheetah and the dogs (**53**) are the best examples.



The skeleton of a kangaroo exhibiting the changed proportions of a leaping animal

Saltatory or Leaping Adaptations

Some animals that are defenceless and much preyed upon are modified for great speed, though along lines that are not conducive to the conservation of energy. These animals progress by long bounds and some use only the rear feet when moving most rapidly. In correlation with this the animals have the hind legs greatly elongated. In some the fore legs are remarkably shortened. The tails of the bipedal animals are elongated and serve to counterbalance the body.

The kangaroos (**5**), are the most widely known of the bipedal leaping animals, but other smaller forms such as the jerboas, (*Jaculus orientalis*, **14**) are more highly modified. Other examples are the kangaroo rats (*Dipodomys*, **29**, **51**), the jumping shrews (*Rhyncocyon*, **7**) and *Tarsius* (**30**).

The giant dinosaur *Tyranosaurus*, exhibited on the fourth floor, though possessing the exaggerated proportions of a jerboa, was not a leaping animal, but like man, was a bipedal runner.

ADAPTIVE RADIATION INTO AREAS OF EXTREME CLIMATE

Desert Adaptations (51)

In deserts, conditions are unfavorable to ordinary mammals. The heat during the day is apt to be extreme; the food supply is often limited to a short portion of the year, as is too, the water supply; there is little vegetation to furnish concealment or nesting sites, and the light color of the background is such as to render most mammals conspicuous.

To escape the desert heat all of the smaller species are nocturnal in habits, and during the day most of them live in burrows, where the temperature is not excessive. To adapt themselves to the short season when food and water are present in sufficient abundance, some of them spend over half the year underground in a state of dormancy called æstivation. For this period of prolonged fast they lay up some stores and put on a large amount of fat.

A few animals, such as the jerboas (**14**, **29**) and kangaroo rats (**29**), require exceptionally little moisture and may never drink, obtaining what they need from their food. In order to be as inconspicuous as possible desert animals are harmoniously light colored.

Arctic Adaptations

On the Antarctic continent there are no land mammals, but over the ice of the Arctic ocean some foraging species wander and in the land areas well within the Arctic Circle there is a rich fauna. The adverse conditions which the mammals must meet here are but an exaggeration of those found in the cold temperate zones; a period of cold weather which is accompanied by a failing food supply, and a transformation of the landscape into an almost unbroken white expanse against which a dark coat is too conspicuous for the success of predator or the preyed upon.

As protection against the cold, northern animals build a layer of fat which acts as an insulator and a reserve food supply. They also have luxurious fur coats for which they are relentlessly pursued by man. To become inconspicuous, some, such as the weasel or ermine, the snowshoe hare (**86**), Arctic hares and the Arctic fox change the dark coat of summer to a white coat. The polar bear and Arctic wolf remain light colored the entire year.

Seasonal coat change in some animals, as the weasel is accompanied by a color change which is protective in the harmony it shows in relation to the usual background

The adverse winter conditions are avoided by many animals by migration or by hibernation. Hibernation resembles a deep sleep, in which the pulse rate and body temperature are greatly lowered and the animal's resources are conserved to the utmost.

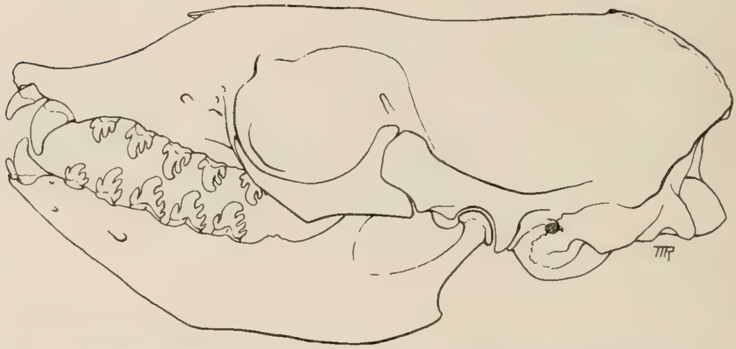
ADAPTATIONS TO SPECIAL FEEDING HABITS

Carnivorous or Flesh Eating Adaptations

Animals that prey on others must have locomotor and sensory adaptation that will enable them to come upon the other creature. In some cases such as among wolves hunting in packs, the predator depends upon long sustained pursuit to wear down the prey. In cats where hunting is usually done by solitary animals the success of the pursuit is generally dependent on a stalk which culminates in a final quick rush or spring. Once upon the prey the animal must be able to overcome and kill it, strong jaw muscles or a blow from powerful fore legs usually accomplishing this object. Most carnivores are provided with long and strong fangs (canine teeth), (**1, 22, 83**) with which they may seize and kill the victim. The incisors are short that they may not interfere with the action of the canines. The jaws are short so that leverage is at its best. The Felidæ (**10**), representing the ultimate carnivorous type, have a pair of cheek teeth modified into large slicing blades that cut the flesh into sizes that may be conveniently swallowed.

Piscivorous or Fish Eating Adaptations

Fish catching animals must first of all be efficient swimmers, and must then be able to seize and hold their slippery, elusive but not powerful prey. For this all of them have sharp recurved teeth which are eminently adapted to this end. Since most piscivorous animals swallow their



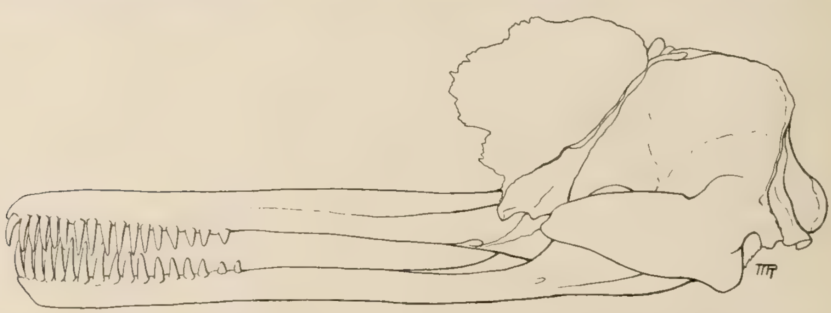
The crab-eater seal has teeth admirably suited to seizing and breaking up the hard shelled crustaceans upon which it feeds

prey whole, the teeth are not adapted to cutting up the fish. This is an advantage for fish bones are sharp and could be troublesome in the throat.

Noteworthy fishers are the otter (**27, 29**), whose smooth body form webbed feet and muscular tail make it one of the most successful of the group, the seals (**13, 28**), and porpoises (**26**). The porpoises are unique in the large number of teeth they possess, over two hundred sometimes being present. It has been suggested that this multiplication of teeth is due to the separation of the lobes of the teeth somewhat similar to those of the sea leopard (**13**).

Blood Sucking Adaptations

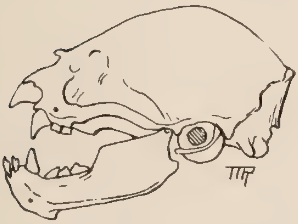
Three genera of tropical American bats live by sucking the blood of other animals which range from chickens to horses. They also are not averse to feeding on men which they attack while asleep. The victim of



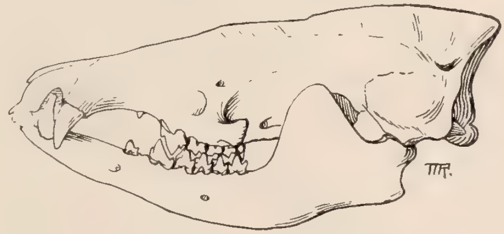
The Ganges River porpoise possesses many needle-like teeth with which it seizes its slippery prey, the fish

such a bleeding does not discover the injury until he awakens the next morning and suffers little inconvenience from it.

The upper incisors of such bats are a pair of large knife-like teeth with which they slice off a bit of the skin of the victim. The molars are small, and the stomach is a thin simple tube no larger than the intestine.



The front teeth of the vampire bat are sharp blades, which cut into the shallow-lying blood vessels of its victim



The tenrec, in common with most other insectivores has sharp teeth and a pointed nose, features attendant upon its insectivorous habits

Insectivorous or Insect Eating Adaptations

Insects are preyed upon not only by a host of small animals typically the order Insectivora and the bats, but also by many larger creatures such as baboons and bears. Such omnivorous species, as the latter, are not primarily adapted to an insect diet and may be omitted from consideration.

Insects are of diverse habits and live in many environments. Though some are soft bodied, many of them have hard shells so that insect eating species must be capable not only of catching the insects but also of breaking this shell. It is for this reason that the little insectivorous bats and the shrews have sharp teeth suited to seizing and breaking up the catch, (**6, 7, 8**). The teeth at the front of the mouth of such insectivores as shrews and hedgehogs are enlarged to enable the animals to seize quickly such active prey. Usually their muzzles are sharply pointed which allows them to seek insects that are in small cavities.

Though all primates probably eat insects, there is only one the aye aye (**30**) which is primarily adapted to such a diet. This animal has large squirrel-like incisor teeth with which it tears open branches that contain burrowing grubs. The second finger is thin and elongated that it may be introduced into insect burrows for extracting the animal. The large

ears of the aye aye may serve to improve the hearing and aid the animal in locating its food.

Certain species living chiefly on ants and termites are considered below.

Myrmecophagous or Ant Eating Adaptations

Several groups of animals have more or less independently become specialized for feeding upon ants or the somewhat similar termites. This has involved the development of strong digging claws to open up the nests, a long tongue for securing the ants, a lengthened skull for the

The giant ant eater has lost all its teeth and its skull is elongated to house the long sticky tongue

housing of such a tongue, and has resulted in the reduction or loss of teeth. Examples are the giant anteater (**50**), the pangolin (**17**), the aard vark (**58**), marsupial anteater (**4**), and the sloth bear which may be seen in the Hall of South Asiatic Mammals. The reader is referred to page 20 of this manual for notes on highly developed ant eating specializations of the manis.

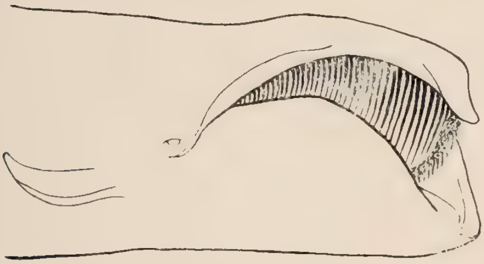
Plankton Eating Adaptations

The whale-bone whales (*Mysticeti*, **26**) are the only mammals equipped to feed on the minute animal life of the sea (plankton). They have lost all teeth but have developed great fringed, horny plates with which they may strain out these minute animals from the sea water as they swim along with mouth open. The gullets of these largest of all whales are very small and suited only to swallowing of small animals. To swallow a creature the size of a man would be an impossible feat.

Herbivorous or Plant Eating Adaptations

In typical herbivorous forms such as the horse and kangaroo the incisors are well developed for cutting off the vegetation, the canines are suppressed, or if present are used only for fighting, and the cheek teeth are large and have broad surfaces.

Animals such as the manatee (**21**), which live on soft aquatic plants have a tendency to tooth reduction, though in some cases, as in the hippopotamus (**18**), the front teeth are strong for digging up the plants.



The whale bone whales have substituted baleen for teeth. This serves as a seive for the water passing through the mouth and strains out the minute animals which are the food of these whales

A sheet of balleen

Species eating tree fruits must be climbers or fliers. Their teeth are usually simple for breaking up or crushing soft plant tissues. The taguans (**7**) and the fruit bats (**9, 20**) are good examples. The fruit bats are often large, slow flying and colonial. They do so much damage in their native countries that their importation into the United States is prohibited. One tribe of Madagascar natives evens up accounts by eating the bats.

Animals living on the bark, buds and roots of trees, and many that have softer fare, are equipped with chisel-like incisors that grow from persistent pulps. The whole group of rodents (**14**) are of this type. Their cheek teeth are typically modified to flat grinding surfaces which finely comminute the food before it is swallowed. The beaver exemplifies the power of the rodent chisel. Trees three feet in diameter have been felled by these rodents.

ADAPTATION FOR PROTECTION

Armor

Though most mammals are covered with soft hair some for protective reasons, have developed an effective armor. The armadillos (**16**) possess a jointed carapace that is reinforced by bony nodules. The pangolins (**17**) are covered with hard horny scales. The porcupines (**15**, **29**) are protected by strong, sharp barbed quills which become imbedded in the flesh of an attacking animal but which cannot be thrown at the enemy. Hedgehogs (**29**), tenrecs (**6**) and the echidna (**3**) are other groups of animals defended by spiny coats that repel an attacker. All of these animals are unprotected on their ventral surface and will usually curl up when attacked, leaving only a forbidding prickly surface to the enemy.

Offensive Odor

The animal kingdom is replete with creatures that make themselves offensive by bad odors. Some of the mammals are justly famed for these special powers of protection. The llamas have the habit of spitting their unpleasant smelling saliva in the face of any one who proves obnoxious to them. Other mammals, find their defence in specialized glands, which in such an animal as the skunk, become invested with a sphincter muscle capable of ejecting the accumulated secretion of the glands. A powerful fluid ejected by the pangolins effects the mucous membranes of dogs or other creatures it strikes and causes serious illness.

Coloration

The concealing coloration of such an animal as the cottontail rabbit or a polar bear seems obvious. Other types of color patterns are, however, apparently conspicuous. The tiger, for example, in a museum case is an exhibit that would be conspicuous in the largest hall. However, when in high grass the tiger's stripes blend in with the vertical lights and shadows of its environment. The skunk with broad white bands is a conspicuous animal to us who stand above it, but the skunk does not need to hide from us. It is by its prey, such as the mice, that it must be unseen. To these smaller creatures of the ground the skunk's dark under parts and light upper parts must blend into the background with some success, the black into the heavy shadows of evening, the skunks hunting time, and the white stripes into the lighter sky. The sloth (**16**) has growing in its hair a microscopic green plant that aids the animal in concealment.

Some cases of supposed concealing coloration are open to question as to the correctness of the interpretation of concealment, but certainly

in the great majority of mammals the coat pattern and color, when seen against the animal's usual background, are concealing. If an animal is a vegetarian it has carnivorous enemies from which it must hide. If it is a meat eater it must be relatively inconspicuous in order to come up to its prey. The usual darker shades of the upper side of an animal may originally have arisen as a protection against over exposure to ultra-violet rays, or other factors. But whatever the original cause for the pattern and coloration, the result has favored concealment.

Escape

The animal that has been discovered by an enemy must defend itself, escape or be taken. The majority of animals invariably attempt to make escape. Burrowing animals scurry to their holes, arboreal creatures dash up the nearest tree, swimmers plunge into the water. Goats and sheep run to the rocky slopes where their enemies cannot keep up with them. Many species not protected by such special environments have only recourse to speed or to artful dodging. Such are the hares, the jerboas, the gazelles and the horses. The greatest speed of few animals is known. The best horses on a short course cannot exceed the rate of thirty-six miles an hour, while racing whippets attain about the same speed. The American pronghorn is reported to attain on occasion a speed of forty-three miles an hour.

Special Weapons

Horns, which may be defined as hard outgrowths of the epidermis occur in the Bovidæ (**18**), Antilocapridæ (**18**) and Rhinocerotidæ (**19**). In the first two families these horns are paired, hollow structures growing over a bony core. In the rhinoceros they are solid and grow along the mid-line. In most of the species which bear them they are used effectively against their enemies and in fighting amongst themselves. The Bovidæ present the greatest variation in horns. These range in shape from the long straight spears of the oryx to the massive coils of the mountain sheep. Only the four horned antelope and a variety of domestic sheep have more than one pair of horns.

Antlers are the periodically shed, branched, bony appendages found on the heads of the Cervidæ (**18**). Though used as defensive weapons, they are commonly employed in fighting amongst the males during breeding season, at which time they have reached their greatest development.

Tusks and fangs are enlarged canine or incisor teeth which are usualy food catching organs, but which are also brought into play for

fighting. The elephant, wild boar, chevrotain, (**18**), musk-deer, walrus (**12**), and narwhal (**26**) possess impressive structures of this sort.

Claws and hoofs though fundamentally locomotor and food getting organs, are also important in defense. The defense of the giant anteater (**50**) lies in the use of its huge digging claws. Ungulates which do not bear horns, antlers or tusks have only their hard tipped feet with which to defend themselves. A giraffe may kill a lion by the forceful blows of the hoofs, and the kicking ability of the horse tribe has saved many of its members from death.

Poison glands emptying through a hollow spur are found only on the hind feet of the male duckbilled platypus and echidna (**3**). It is supposed that these are used principally in fighting among the males.

Autotomy

Many of the lower animals such as crabs may break their own appendages at will in order to free themselves from an enemy. There is no comparable phenomenon among mammals except in certain rodents, among them the pocket mice (*Perognathus*, **14**), where the animals may break off their tails, when seized by that member, by running in small circles. The skin covering the tails of many other rodents will slip off if the animal is held by the tail.

Size

Some of the animals are practically immune to attack because of their size. An adult elephant or rhinoceros has nothing to fear from any mammal other than man. The largest whales, though are subject to attack by the killer-whales which run in packs and tear out the tongues of their larger relatives.

Social and Mental Traits

Mammals of some species protect themselves by pugnacity, charging any potential enemy on little provocation. An enemy is less likely to trouble an animal that is always ready to fight than one whose habit is to flee. It takes a brave animal to attack a big baboon who is equipped to fight and is ready to do so. Herbivorous animals herd together that the enemy will be the more likely to be discovered and that it may be successfully repulsed by the concerted action of the herd. Among some species a few members of the large herd will act as sentinels and give warning to others that are feeding. When wolves attack musk oxen the adults form a ring around the younger ones and all face outward so that the enemy must brave a continuous circle of forbidding sharp horns

VARIATION AND HEREDITY

The development of an individual is an exceedingly complex matter the nature of which we are only beginning to understand. The wonder grows that we are so closely alike, that variation is so small in extent. Variation is, however, of many sorts. In part it is due to changes in the germ cells and these we call genetic. Such changes are the ones that natural selection and other evolutionary processes must work from.

Other changes are due to environment, to give this term a significance so broad that it includes anything from sunlight to the influence of surrounding organs. These variations so far as we know, are never hereditary. The exact mechanism by which genetic and environmental variations are produced is imperfectly understood in all but an infinitely small number of special cases. Such variations as occurs between different races of dogs, though genetic in its background, is in some features attributable to the inheritance of certain types of glands of internal secretion. This effect is shown in Case 23 where a bulldog, a blood hound and a borzoi represent glandular strains. The bulldogs are typical achondroplastic dwarfs that owe their condition to deficient thyroid activity. This condition produces in dogs or men a stocky body with short twisted limbs and muscles that are short, thick and knotty. The base of the skull is short. the nose bridge low, and sunken, the forehead overhanging, the jaw undershot and the face flat.

The bozoi and the bloodhound are races in which the anterior lobe of the pituitary, a gland associated with the base of the brain, is overactive during part of the life. The secretion (hormone) of this gland, tethelin, stimulates growth, and when released in such quantities as to over-balance its natural checks, produces gigantism. This gland is overactive in the borzoi before the bone sutures close and as a result the bones grow to great length. In the bloodhound this same gland is overactive before the bone sutures close, with the result that these dogs develop large coarse features and loose skin, a condition named acromegaly.

The gonads of each sex secrete special hormones which produce the secondary sexual characteristics.

The environment may act directly on an animal to produce other variations. The tail length of rats is determined, within limits, by the temperature of the environment during growing period. The coat color of Siamese cats is similarly controlled by temperature.

Considering the end result, variation is correlated with several factors which may be considered separately.

Age Variation

From birth to death every mammal undergoes pronounced changes of size, proportion, coloration, habit and other characters. Striking changes in color pattern often occur. The young of the wild boar are prominently striped, as are those of the tapir. The young of many deer and cats are spotted when adults of these same species are not (**84**). Age changes in the skull (**24**), usually include the increase in size, closure of sutures, appearance and loss of a first or milk dentition, and the appearance and loss of a second set. As age progresses the ridges of the skull tend to become more pronounced in accommodation to increased muscle size.

Seasonal Variation

Animals in temperate and polar climates often undergo two complete changes of pelage annually, one of which is adapted to winter cold and the other of which is lighter for summer warmth. Frequently a color change accompanies this change in coats (**84**). The winter coat occasionally, as in the hare (**86**) the weasel and Arctic fox, is white in contrast to a dark summer coat. Other examples of seasonal variations are the growth and shedding of antlers among the deer, and the many changes due to seasonal differences in habits and nutrition.

Sexual Differentiation

Though the sexes of most mammals are colored alike, there are often differences in size and fighting equipment.

The male and female nilgai and black buck to be seen in the Hall of South Asiatic Mammals, are differently colored, as are some of the primates such as the mandril and gibbon. Male mammals are usually larger and more powerful than their mates, Instances of this disparity is size may be noted in the Virginia deer (**84**), and in many of the habitat groups of mammals in other halls. Fighting weapons such as the spurs of the platypus (**3**), the antlers of most deer (**18, 84**), and the tusks of the boar (**18, 83**) are either developed only on the males, or are better developed in that sex. The fighting among males during the breeding season is conducive to racial betterment, for in this manner the stronger males more frequently produce offspring and the weak individuals are either killed or kept from the females.

Geographical Variation

Geographic variation is intimately tied up with environmental change. Species with broad geographic spread are in most cases distinctly different in various parts of their ranges. These differences

concern coat color, size and proportions. When a form becomes isolated, as on an island, the fortuitous genetic variation arising within the species are likely to become fixed more readily than they would be within the main range of the species where greater mixture and, possibly, different enemies weaken the chance of survival of changed types. Geographic variation among mammals, notably among the white-footed mice (*Peromyscus*), is associated with change in backgrounds. Species inhabiting areas of white sands have become extremely light in color, while forms living on areas of black lava reach the opposite extreme of dark coloration.

Mutational Variation

There is a tendency for the structure upon which heredity depends to change or mutate from time to time. These changes which take place in the germ cell give rise to changes in the individuals. Should these changes be favorable the animal's chance of survival to breed and transmit the new character will be enhanced and by such changes evolution takes place. Not all such mutations are, however, favorable. Some, such as those responsible for the disappearance of pigment (albinism, **27, 85**) are unfavorable since the albino animal is more conspicuous and has eyes that cannot function well due to lack of protective pigment. As a result albino strains do not become established except where they are protected from enemies by isolation. The over production of pigment or melanin, produced occasionally by mutation, gives rise to black animals or melanos (**27**), which for one reason or another rarely become established.

The lineal transmission of mutations among mammals is illustrated in Darwin Hall on the first floor.

Size

The size of mammals is adapted to the feeding and locomotor habits, and to the environment. Burrowing mammals are small because of the mechanical difficulties attending the construction of large tunnels, and because of the impossibility of securing a large amount of food underground. The size of arboreal mammals is limited by the strength of the trees which support them. Aquatic mammals reach the extreme of size because in their environment food is plentiful and the density of the water medium buoys up the great weight of the animals.

The smallest mammal is probably a Virginian shrew, *Microsorex hoyi winnemana*, with a body length of two inches and a weight no greater than that of a slightly worn American dime. The largest mammals that exist or ever lived are the blue whales, which may attain a length of 103

feet. Their maximum weight is not known, but the 70 foot whale whose model is exhibited in the middle of this Hall weighed 61¾ tons.

The largest living land mammals are the African elephants, the tallest measured specimen having attained eleven and one half feet at the shoulder. "Jumbo" a famous captive elephant whose skeleton is exhibited in this Hall, stood ten feet ten inches at the shoulder and weighed four tons. A few fossil land mammals are known that are larger than this.

PRINCIPLES OF THE CLASSIFICATION OF MAMMALS

In order that the relationships of animals may be understood it is self-evident that we must first know the existing species of animals. It is to this end that the efforts of many of the departments of the Museum are largely devoted. Because of the enormous numbers and infinite geographical variations of mammals it is necessary to collect large series of specimens from all parts of the world. To exhibit such a wealth of material would not be feasible, nor would anything be gained by it. The great majority of specimens go into study collections of the Museum where they are studied and classified. These specimens form raw material on which all critical studies of animal distribution and relationships must ultimately rest.

Modern methods of classification aim not only to so describe and classify forms that they may not be confused, but attempt as well to express the evolutionary relationship of an animal to other species.

The system of naming which all workers now follow was founded by Linnæus in 1757. All species are given a *specific* name which is always combined with another name, the *generic*, which it shares with other closely related species. Thus the lion and domestic cat both bear the same generic name, *Felis*. The domestic cat, however, is known under the name of *Felis domesticus* whereas the lion is named *Felis leo*. To this combination is sometimes added a third name which designates a geographical variety or subspecies of the species. Thus the Asiatic lion is named *Felis leo persicus*. The genera of mammals may be readily associated with other related genera and such groups form families. The genus *Felis* and the genus *Lynx* (lynxes and bobcats) are clearly related and are placed in the same family, the Felidæ. The family Felidæ is only one of several families of flesh-eating mammals which together constitute one of the orders of mammals the carnivora. The entire range of orders shown in the Hall together with certain extinct orders constitute the class Mammalia, while the mammals, birds, reptiles,

amphibians and fishes are all classes of the phylum Chordata, a group composed of the vertebrated animals and certain aberrant sea living animals which show affinities with the vertebrates.

WHY A SCIENTIFIC NAME?

To many people a scientific name appears as an unnecessary and cumbersome appelation. It has proved impossible to use common names for animals since one species may bear a half dozen common names in a single country, and one name is often applied to several species of mammals. As examples, the rabbit's small cousin *Ochotona* (**14**) is known in the western United States as pika, rock-rabbit, haymaker and cony, whereas cony is used not only for *Ochotona*, but also for the hyraxes (order Hyracoidea, **19**). *Ochotona*, on the other hand, applies to all and only those of a group of related species whose distribution extends over two continental masses where it probably has as many as thirty "Common" names. The rules of scientific nomenclature specify that a name used for one genus of animals cannot be used for any other.

That scientific names are not necessarily too difficult is shown by the popular adoption of such scientific names as *Rhinoceros* and *Hippopotamus*. Some scientific names may be of extreme shortness such as that of a Philippine bat which is called *Ia io*. Others, it is true, are more formidable as may be illustrated by the name of a fossil mammal, *Brachydiastematherium transilvanicum*.

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COMETS, METEORS, AND METEORITES

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By CHESTER A. REEDS
CURATOR OF GEOLOGY AND INVERTEBRATE PALAEONTOLOGY

AHNIGHITO, A CAPE YORK, GREENLAND METEORITE

Reprinted from Natural History Magazine for May-June, 1933

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GUIDE LEAFLET SERIES, No. 77

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NEW YORK, 1933

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Artist's Sketch of Successive Explosions of a Meteor. By T. W. Voter

COMETS, METEORS, AND METEORITES

Mysterious Travelers of the Sky—Their Origin, Action, and Composition

By CHESTER A. REEDS
Curator of Geology and Invertebrate Palæontology, American Museum of Natural History

COMETS, meteors, and meteorites are usually regarded as three distinct cosmic phenomena. They seem to be connected, however, by relations of origin and association founded upon well authenticated observational evidence. These phenomena appear but occasionally and are singular and mysterious in aspect. In appearance comets and meteors resemble one another, for they both have luminous heads and nebulous tails, but as far as space relations are concerned they are separated by millions of miles. Comets, which are the most distant, are those erratic members of the solar system which move in elongated orbits about the sun. Their masses are exceedingly small when compared to their size, for they are generally surrounded by hazy or nebulous envelopes. Meteors, on the other hand, are transient cosmical bodies which enter the earth's atmosphere from without and become luminous as they shoot across the sky. Meteorites are masses of matter from outer space which have fallen upon the earth's surface. They consist usually of stony matter with varying amounts of metallic iron and nickel; more rarely of nickeliferous iron and much more rarely of stony matter with little or no metal.

For untold centuries man has looked at the starry canopy of the heavens at night and marveled at the wondrous display of the moon, the planets, and the multitude of stars set in constellations or in the Milky Way. During the day this same canopy impresses him in a different manner, for, due to the strong light from the sun, the zenith appears to be sky-blue and a sense of emptiness and vacancy is in evidence everywhere except for the clouds that may form in the lower levels of the

HOBA WEST SIDERITE
This fell near Grootfontein, Southwest Africa. This find (1920) is reported to be the largest single mass of meteoric iron known (3×9×9.67 feet) 60 metric tons, 132,300 lbs. Iron 83.44%, nickel 16.24%. It shows no lines—an ataxite

atmosphere called the troposphere. The stars and planets which are prominent on clear nights can seldom be seen in the daytime except from the depths of a well, a cave, a cañon or through a telescope.

Man has discovered from such observations spread over many centuries that these various celestial objects have regular yearly movements, that they are governed in their course by definite physical laws, and consequently he has grown accustomed to their regular movements, for he sets his clocks and watches by sidereal time, predicts the time of eclipses to within a few seconds of their happening, plants and harvests his crops according to the seasons, makes his home on the earth and plans his business undertakings for the coming year with full confidence that these bodies will continue their accustomed movements and functions.

On the other hand it has been more difficult for man to visualize the daily and yearly movements of the earth, as one of the planets of the solar system, for he, with his buildings, railroads and other works, is carried along unconsciously with the earth as the entire solar system moves through space towards the star Vega. The earth rotates on its axis at the rate of 17.28 miles a minute at the equator and travels at a speed of more than 1000 miles a minute along its path around the sun.

While these celestial and terrestrial phenomena are profound and have engaged the attention of scientific men and philosophers for more than two millenia, the occasional appearance of comets, and the not infrequent flight of meteors and meteorites have aroused special attention, for these phenomena are as yet not fully understood. Comets, meteors, and meteorites appear by day or by night. They are seen in flight more clearly by

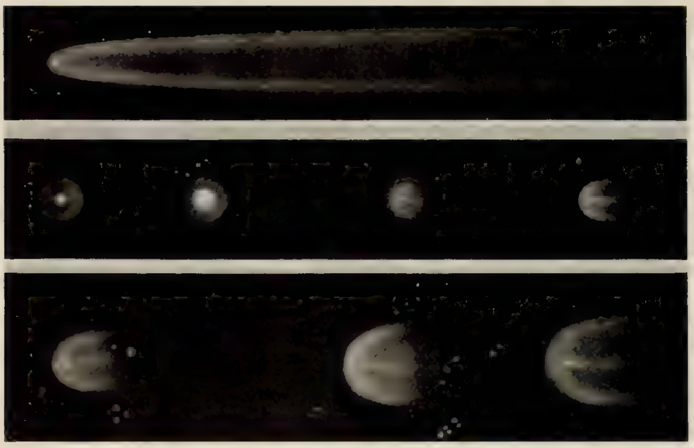
OLLAQUE SIDEROLITE, OLLAQUE, BOLIVIA
The polished surface shows olivine masses filling meshes of nickel-iron network

ARTIST'S SKETCH OF METEOR FALLING AT NIGHT. BY T. W. VOTER
Meteors pass through the atmosphere at speeds varying from eight to fifty miles per second

night than during the day for at night their light is apparently stronger.

Comets are rarely conspicuous, for less than ten per cent of the several hundred thousand in the solar system can be seen with the naked eye. They vary considerably in size, some of the smallest have approximately the diameter of the earth; while the Great Comet of 1811 exceeded the size of the sun and had a diameter of fully 1,000,000 miles. The average size of many of them is 80,000 miles. Comets, which move in highly elliptical orbits of great extent are, according to Kepler's laws, much more rapid in their motion when near the sun than when far away. Moreover, since most of them are illuminated only during the short interval when they are near the sun, they travel most of the time in the cold realms of space as dark objects or faintly luminous bodies.

Comets usually have a brilliant head and tail when seen near the sun. The long tail, if present, generally streams across the sky for millions of miles in directions away from the sun. The brilliant head is hazy and nebulous in appearance and may change in size when swinging through that portion of its elliptical orbit nearest the sun, called perihelion. Although the head may be great in size its mass is exceedingly small, being less than that of the major planets. Within the head a sharply defined star-like nucleus is usually visible. This nucleus is generally believed to be composed of a swarm of meteors and meteorites, whereas spectrum analyses show that the outer portion of the head consists of the extremely rarefied gases cyanogen and carbon monoxide. The tail is not in evidence when the comet is far from the sun, but, as the sun is approached, an atomic activity is set up within the head and electrons are driven off into space to form the tail. Some force, perhaps the sun's light pressure, radiation pressure or electrical repulsion within the comet's



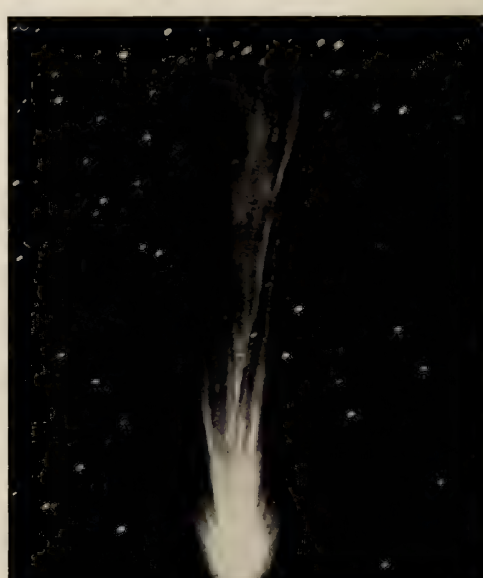
HALLEY'S COMET

C. P. Smyth's drawings of Halley's comet, 1835–1836. From Chamber's *Story of the Comets*

head, is responsible for the lighted tail. As shown by an accompanying drawing, the tail points away from the sun even after the comet has passed around the sun and starts on its return trip. Then the tail precedes the body of the comet. At various times the tail has been observed to consist of various streamers emanating from the head.

It would seem that those particles of matter which are driven out of the head to form the tail are lost and must be constantly renewed, for it has been noted that comets whose orbits are small and pass frequently about the sun are relatively faint and often devoid of a tail. May it not be that their frequent passage about the sun has deprived them of the gaseous tail-forming material?

Comets or at least some of them follow regular orbits. Newton, in studying the comet of 1680, ascertained that, according to the laws of gravitation, the path of a comet should be an elongated curve, and represented the course of such a body mathematically. Halley, in 1704, collected the observations on 24 comets, calculated their orbits, and found that the comet of 1682 had a path round the sun similar to that of the comets of 1456, 1531, and 1607. He recognized them as recurrences of the same comet and, although their periods were not exactly equal, due to interference by the planets Jupiter and Saturn, he predicted that this comet would return, subject to the influences of the planets, about 1758. Other astronomers took up the calculations of the algebraical and numerical formulæ and determined that Saturn would delay the return of Halley's comet 100 days and Jupiter 518 days, a total of 618 days. The comet was observed to pass perihelion on March 12, 1759. It returned again on November 15, 1835, after completing its course in 28,006 days. In 1873 it reached aphelion and returned once more in 1910. Halley's comet thus has an average period of about



Photograph by Max Wolf

COMET MOREHOUSE (1908 III)

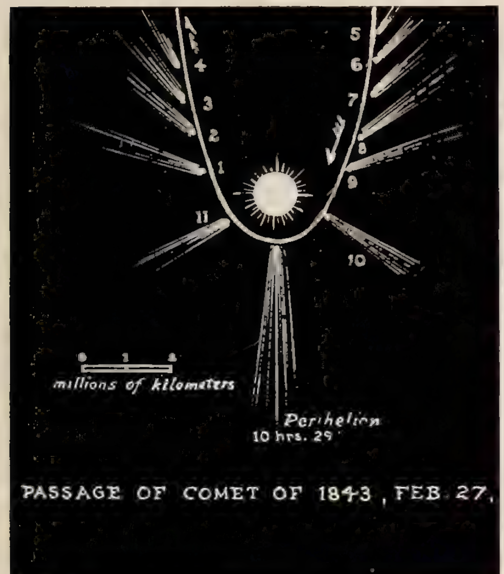
Discovered November, 1908, by D. W. Morehouse at Yerkes Observatory, Wisconsin. A series of parabolic hoods enclose the head of the comet. From *Handbuch der Astrophysik*, Band IV

COMET RORDAME
July, 13, 1893. The camera moved with the comet, hence, the stationary stars show as short white lines

Photograph by E. E. Barnard, Lick Observatory, Calif.

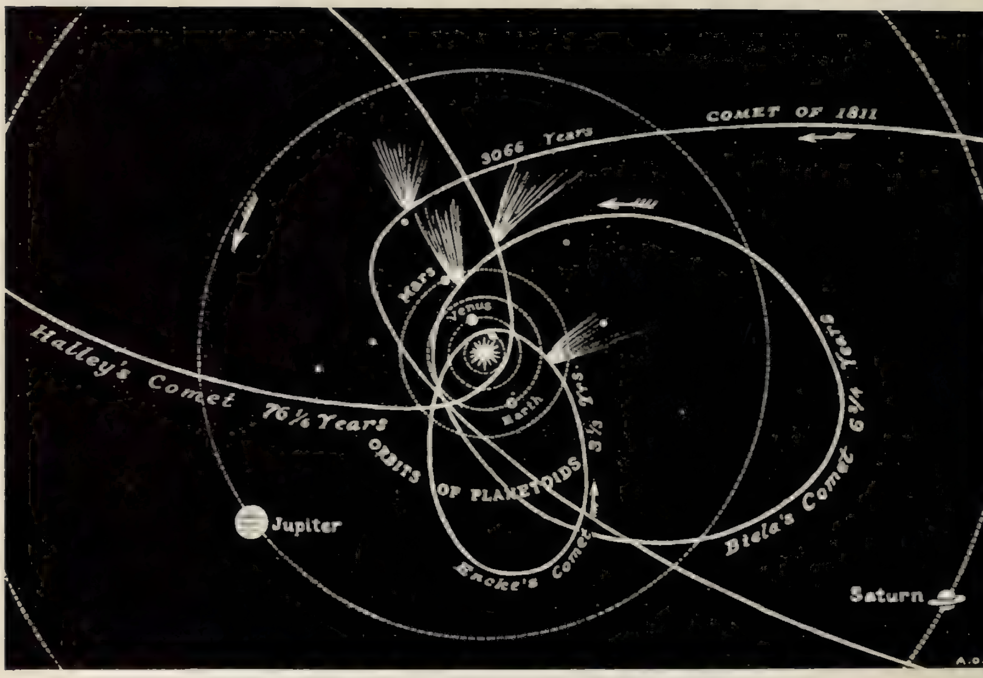
76⅙ years. These calculations and observations removed comets from the domain of legend and established them as part of our solar system.

The periodicity of a considerable number of comets has been confirmed. Of these Encke's comet, discovered November 26, 1818, is the "Mercury of Comets." It completes its elliptical orbit of 2,324,060,000 miles in 3.3 years. It is brightly lit up when it passes within 31 million miles of the sun and may then be readily seen with a telescope. In its revolutions it is also affected by planetary disturbances as are some 60 other comets with known periods of less than 80 years. Astronomers divide this assemblage of comets into four groups and name them after the four major planets, Jupiter, Saturn, Uranus, and Neptune. Jupiter's family, the largest, has some fifty members including Encke's comet, with periods 3.3 to 8.9 years; Saturn's family has four members with periods 13.1 to 17.7 years; Uranus has two with an average period of 36.6 years; Neptune's family has nine members including Halley's comet with a mean period of 70.0 years. The influence of Jupiter on the first group has been for the most part established, but the connection of other planets with their assigned members is not universally recognized.



SECTION OF A COMET'S PATH
Passage of the comet 1843 about the sun. This comet covered the perihelion portion of its orbit, twelve million kilometers, in ten hours The tail pointed away from the sun

There are a number of instances on record which show that not only the orbits, but also the comets themselves, may be considerably affected by passing near the planet Jupiter. For instance, the orbit of Lexell's comet of 1770 was so changed in 1779 that it could not be seen. In 1770 it passed within one and a half million miles of the earth. Changes have also been noted in d'Arrest's comet 1860, Brook's 1886, Wolf's 1875 and 1922. The 1922 perturbations of Wolf's comet modified the orbit to such an extent that it took a course nearly the reverse of that of 1875. Biela's comet whose period of 6.75 years was established in 1826 had been seen in 1772 and 1805. Its orbit



ORBITS OF SOME COMETS AND PLANETS

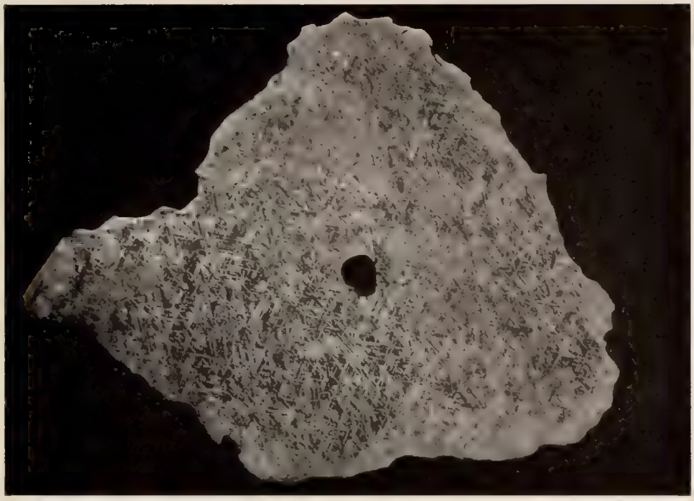
While the earth encircles the sun in one year, Encke's comet takes three and one-third years, and other comets a longer period. Most comets have paths which do not lie in the plane of the earth's orbit

was found to intersect that of the earth's, and in 1832, when it returned, there were many needless apprehensions. It was not seen in 1839, but in 1846 it was found to have split into two comets, which travelled side by side. In 1852 it reappeared with the two comets farther apart. It was not seen in 1859 or in 1866, and for the years 1872, 1885, 1892 and 1898, there was no comet, but instead brilliant showers of meteors. Other known comets have also disappeared, namely: Brorsen and Temple I, in 1879. The Pons-Winnecke comet with a period of 5.6 years has also attracted considerable attention because of irregularities in its orbit and its period. Discovered in 1819, its perihelion distance, although changed every alternate revolution by Jupiter, remained within the earth's orbit up to 1915, when it went outside. In June, 1916, and June, 1927, there were meteoric showers, which were associated with this comet. Some astronomers would also connect this comet with the great meteoric fall, which crashed into an uninhabited region of central Siberia in 1908, where, after the reported appearance of a great light followed by many detonations, an area of some 1,000 square miles, was completely devastated.

The most prominent member of Saturn's family is Tuttle's comet, discovered in 1858, with a period of 13½ years. It has been seen at every return since 1858.

Temple's comet, discovered in 1866, is the more notable of the two comets of Uranus. Its period of 33 years and its orbit coincides with that of the Leonid meteors with brilliant displays in November, 1833, 1866, and less so in 1899, since perturbations of Jupiter had changed its course. Its motion is retrograde to that of the planets. Stephan's comet seen 1867, but not since, is the other member.

Of Neptune's nine comets five have been seen a second time. Halley's is the best known. It has been traced back to



IRON METEORITE FROM GIBEON, SOUTHWEST AFRICA

A black carbon nodule appears near the center of the polished and etched surface; Widmanstätten figures cover the remaining portion of the slice

240 B.C. On various occasions it has approached near enough to the earth to give meteor showers. It was observed in 467, 1066, 1456, 1531, 1607, 1759, 1835 and 1910. It crossed the sun in 1910, but since it was then invisible, it demonstrates the very small amount of matter remaining in it.

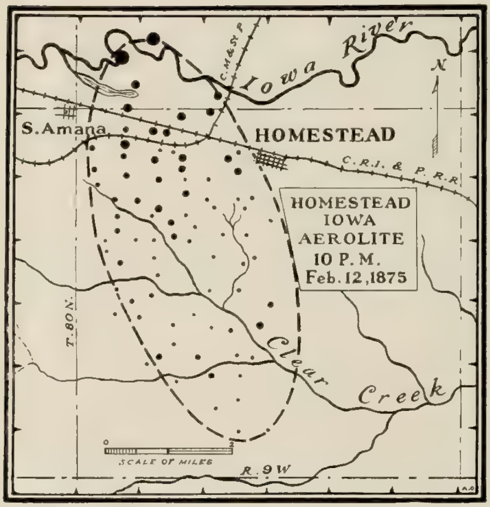
Other comets with periods ranging from 119 to 165 years have been observed, and one with a period of 335 years suggests a family belonging to an extra Neptune planet.

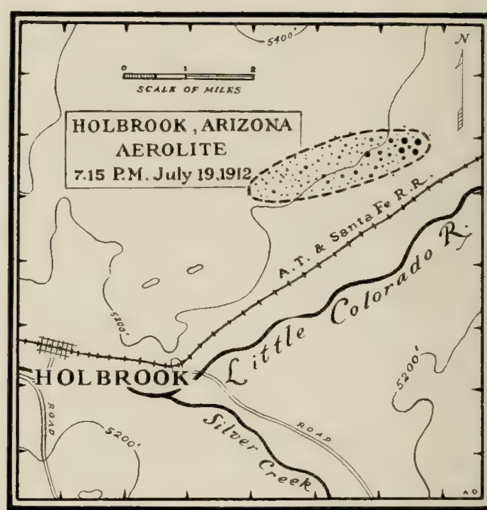
In this connection it should be stated that while comets may be seen at various times as they pass about the sun, meteors can be seen only when they enter the earth's atmosphere. In various instances it has been noted that where comets approach or cross the orbit of the earth, or disintegrate, meteoric displays have been observed.

Not infrequently on clear nights faint moving sparks of light may be seen to emanate sporadically from the starry canopy and increase in brightness as they move rapidly towards the earth, but seldom reach it before quickly and silently disappearing. Such objects are called "shooting stars" or small meteors. Occasionally, a brilliant streak of light with a more or less well-defined head called a "fireball" or "bolide," accompanied by a hissing sound and detonations, will light the sky momentarily and strike the earth at a place near or beyond the range of vision of the observer. These are also meteors, but of a larger size than the shooting star type. Perhaps a cloud of dust will be seen to rise from the place where it struck and its lodgment can be definitely located. When the spot is approached, there may be seen a newly made hole, one or more feet in

A PORTION OF THE ROSE CITY, MICHIGAN, METEORITE

Composed of a network of stone and metallic masses with a black crust appearing on the upper and lower margins





(*Left*) THE HOMESTEAD, IOWA, SHOWER.—Showing a characteristic ellipsoidal area, 3×6 miles. Pieces weighing 32 kilograms were found along the northern margin. (*Right*) THE HOLBROOK, ARIZONA, SHOWER.—The ellipsoidal area is 1×3 miles in extent. Many thousands of small fragments have been recovered

depth with an object in the bottom of it. The object may be either a stone with a blackened surface or an irregular mass of metal marked on the front or "brustseite" with shallow furrows and subconical pits, and on the rear side with depressions called thumb-marks or "piezoglyphs." Sometimes the thumb-marks are found on all surfaces. These markings are due to superficial heating produced by friction with the air. Whether the object has a stony or metallic aspect its appearance will be unlike any terrestrial rock or stone and may be called a meteorite.

Stony meteorites often fall as showers due to the fact that the original mass explodes or bursts one or more times before reaching the earth. The areal distribution of the stony fragments on the surface of the ground usually assumes the form of an ellipse varying in size from one-half mile in width to three in length as in the 1912 Holbrook, Arizona, fall, or three by six miles as in the 1875 Homestead, Iowa, fall, or three by ten miles as in the 1924 Johnstown, Colorado, fall, as shown diagrammatically in this article. The individuals of a shower are distributed according to their momentum, those of small size with less momentum will reach the ground first, while those of large size and greater momentum will be carried farther. This fact affords corroborative evidence in determining the direction of the path of the meteor. A comparison of the diagrams will show that the Homestead meteor traveled in a N.N.W. direction, the Holbrook in an E.N.E. direction and the Johnstown in a N.E. direction.

Nickel-iron meteorites are often found in single masses, yet in the case of the Cape York, Greenland, irons two large masses were found on one island, and one each on two near-by islands, suggesting a single fall. The large mass, Ahnighito, 36½ tons, the Woman, 3 tons, and the Dog, 960 pounds, are in the American Museum. The other piece, 3.4 metric tons, is in the Royal Museum at Copenhagen, Denmark. The Bethany irons in southwest Africa have been found singly in rather widely separated areas, yet when their distribution is plotted it suggests a shower. The most recent find in this region is that of Hoba West iron near Grootfontein, Southwest Africa. It is estimated to weigh 60

metric tons and is reported to be the largest single mass known.

Mr. Hirn, writing in *L'Astronomie*, June, 1883, calculated that a bolide entering the upper regions of the atmosphere with a relative velocity of 18.64 miles per second, compressed the air in front of its path from one-hundredth of an atmosphere on entering to 56 atmospheres at a height of 23 miles. He also determined that with increase of pressure there is an increase of heat and a rise of temperature on the exterior surface to points higher than can be produced in the laboratory. The temperature of space is 273° below zero Centigrade. It is assumed that the bolide had this temperature before entering the earth's atmosphere. If so, then its surficial temperature was raised from —273° C. to 3,340° C. in the few seconds of is flight. If this calculation be true it is readily understood why a meteor becomes visible on account of this transformation of its motion into heat and light. Neither is it difficult to perceive why the small masses of "shooting stars" are consumed, why the larger stony masses with low conductivity are rent into fragments by explosions, and why the more tenaceous irons usually remain intact and have irregular outlines and pitted surfaces.

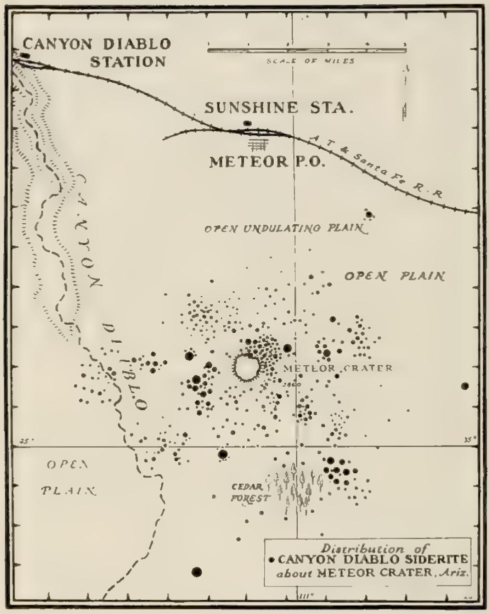
THE JOHNSTOWN, COLORADO, SHOWER

Four terrific explosions were heard accompanied by "smoke" puffs, before the fragments were spread over an ellipsoidal area some 3×10 miles in extent

It is also known that the greater the air pressure the more the velocity of the meteor is checked. This fact would explain the shallow depth of the holes made in the ground by most meteorites. The height at which some meteorites lose their initial velocity is quite variable. On the basis of some nine, which have been studied, it varies between 2 and

THE JOHNSTOWN, COLORADO, AËROLITE

One of the thirteen pieces found showing a thin black crust and a gray stony interior. Rounded and angular particles of greenish-gray pyroxene are in evidence in the gray field



SKETCH MAP
Showing position of Meteor Crater and the Canyon Diablo Meteorites

29 miles above the surface of the earth. Some few meteors, however, have made great holes in the ground.

The most remarkable occurrence of iron meteorites associated with a meteor crater is in Yavapai County, Arizona, near the intersection of the 111th meridian and 35th parallel. The meteorite, which is called Canyon Diablo, after a near-by erosion feature, consists of thousands of pieces of variable sizes scattered over an oval area about nine miles in diameter. A depression known as Meteor Crater lies in the center of the meteorite field. This crater is quite large being 4150 feet in diameter and 570 feet deep. It is surrounded by a parapet 150 feet in height composed of rock débris thrown out of the crater. The crater has been studied at various times from different standpoints and the present general consensus of opinion is that it was formed by the impact of a great meteor or comet with the earth some 50,000 years ago, and that immediately following the impact there was a tremendous explosion which not only scattered the meteorites and rock débris over the surrounding plain, but gouged out the crater pit and greatly disturbed the normal disposition of the thick limestone and sandstone beds in the margins of the crater. Borings have been made within and about the margins of the crater in an endeavor to locate a possible larger meteoric mass, but so far they have yielded only inconclusive results.

Other meteor craters and associated

THE CANYON DIABLO METEORITE
A large mass of the Canyon Diablo siderite in the American Museum. Total weight of fall unknown; six tons preserved in collections

meteoric material have recently been found at Henbury, Australia and Odessa, Texas. No meteorite fragments, however, have been found near the meteor craters of Tunguska, Siberia, and Kaali, Esthonia.

So seldom are meteorites seen to fall that it is not strange that such phenomena should attract widespread attention whenever and wherever they occur. Neither is it strange that skepticism should arise in the minds of non-witnesses regarding the existence of objects which are reported to have fallen from the heavens.

Early records show that meteoric showers were regarded as supernatural. According to the late G. P. Merrill of the Smithsonian Institution, such phenomena are referred to in Revelations VI, 13; VIII, 10; and XII, 3, 4. E. F. F. Chladin in 1819 stated that one of the oldest meteoric falls on record is that of Crete, 1478 B.C. Pliny in his second book, *Naturale Histoire*, mentions that in 468 B.C. a Greek philosopher, Anaxagoras Clazomenius, foretold that with the appearance of a comet a stone should fall from the sun. Such a stone did fall at Abydos and was held in great reverence. Records also show that at 11:30 P.M., on November 7, 1492, a meteorite fell at Ensisheim in Ober-Elsass, Germany. This stone was regarded as a miracle of God and by order of King Maximilian the main mass, weighing 260 pounds, was placed in the church at Ensisheim. This meteorite is of interest in that it constitutes

Photograph by Clyde Fisher

METEOR CRATER, ARIZONA, FROM THE RIM
Looking across the crater pit, 570 feet deep and 4150 feet in diameter

AIRPLANE VIEW OF METEOR CRATER, ARIZONA
Taken by Clyde Fisher, January 12, 1933, with snow on the ground. Canyon Diablo and the San Francisco Mountains in the background

the oldest known fall of which samples of the specimen have been preserved.

As noted by Dr. O. C. Farrington, 1915, the first stony meteorite observed to fall in America, and which was described, was that of Weston, which fell 6:30 A.M., December 14, 1807, in Fairfield County, Connecticut. In commenting upon this fall Thomas Jefferson, President of the United States, expressed the prevailing opinion in regard to meteorites when he said that it was easier to believe that Yankee professors would lie than to believe that stones would fall from heaven.

The brilliant display in November, 1833, of shooting stars, later known as Leonid meteors, associated with Temple's comet, brought forth a decided change in the general attitude of the public in regard to meteoric phenomena.

With this change in attitude it is interesting to note by centuries the record of meteorites which were seen to fall and portions of which have been preserved. Referring to G. P. Merrill's 1929 list of 482 falls, we note that for the 15th and 16th Centuries there is one each; for the 17th, three; for the 18th, nineteen; for the 19th, three hundred forty-two; and for the first third of the 20th, one hundred sixteen. This shows quite conclusively that during the centuries when meteorites were regarded as being supernatural, few specimens were found, and that during the 19th and 20th Centuries, when they received attention, many were recovered.

Out of a total of 482 seen to fall, 458

A GREAT BOLIDE OR METEOR, AS SEEN THROUGH A TELESCOPE
Photograph by Josef Klepesta at the Prague Observatory, September 12, 1923. The white spots are stars. The bolide is the white streak of varying width. It crossed the field of the camera as the great spiral nebulæ in Andromeda (center) was being photographed

SHOOTING STAR AS SEEN THROUGH A TELESCOPE

Nebulæ in Cygnus to the right. The stars show as white dots. Photograph by E. E. Barnard, Yerkes Observatory, Wisconsin, July 15, 1909

represent stony meteorites, 5 stony-irons, and 22 nickel-iron meteorites. Stony meteorites are thus seen to fall more frequently than the iron meteorites, of which 350 had been found to 1929, but only 22 seen to fall. The number of falls and finds known in 1929 was 832. The list has been considerably increased during the following four years. The American Museum Collection of meteorites (March, 1933) contained 2640 specimens, representing 569 falls and finds.

Large collections of meteorites reveal that the specimens of no two falls are exactly alike in structure or composition, yet it has been observed that they may be arranged into three principal groups or kinds, as noted by Merrill namely:

1. Aërolites, or stony meteorites, consisting essentially of silicate minerals with minor amounts of the metallic alloys and sulphides.
2. Siderolites or stony-iron meteorites, consisting of an extremely variable network or sponge of metal, the interstices of which are occupied by one or more silicate minerals.
3. Siderites or iron meteorites, consisting essentially of an alloy of nickel-iron with iron phosphides and sulphides.

Technical students of meteorites have subdivided each of these groups. The aërolites and siderites are, however, the more common kinds. When cut, polished and etched, the siderites, or iron meteorites, usually show peculiar markings of crossed lines, and thus can be easily distinguished from the terrestrial irons.

Some siderites have the nickel-iron alloys arranged in the form of plates parallel with the faces of an octahedron. These lamellae may be of different degrees of thickness and composed of one, two or three kinds of metal. On etching with acid these metallic bands react unequally

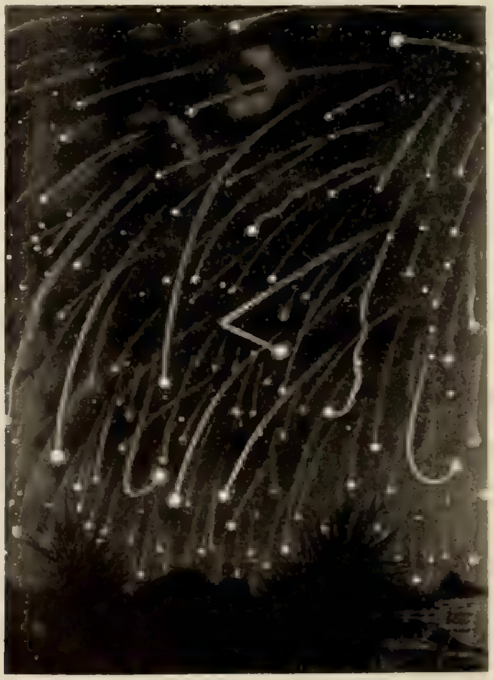
and show characteristic figures known as Widmanstätten lines.

Another group of iron meteorites, composed of homogeneous masses of nickel-iron, show cleavage and lamellae parallel to the faces of a hexahedron. This is due to the twinning of a cube on an octahedral face. On etching with dilute nitric acid the structures show Neumann lines. Such forms are known as hexahedral irons.

A third group of irons are called massive irons or ataxites because their structure is amorphous and shows neither Neumann or Widmanstätten lines or other pronounced features.

The structure of the aërolites is quite different. They resemble the light colored felsitic rocks of the earth's crust, but they are unlike them. Aërolites may be granular, crystalline, chondritic, basaltic, tuff-like or breccia-like and with or without veins. Metallic shreds may or may not be scattered through the mass. While the color is usually light gray, it may vary through various shades of gray to black. A characteristic feature of aërolites is that while their interiors may be gray in tone, with various chondrules or mineral grains in evidence, their exterior surfaces are always coated with a thin black crust, which varies in thickness from $\frac{1}{64}$ to $\frac{1}{32}$ of an inch.

Astronomers tell us that about 400,000,000 celestial objects enter the earth's atmosphere every day, that about 20,000,000 are large enough to form shooting stars or meteors, and that of this number a minimum of but one per day is of sufficient size to reach the earth and constitute a meteorite. At first it may seem strange that so many meteors enter the atmosphere and so few reach the earth. When it is recalled, however, that meteorites vary from sizes microscopic to objects measured in tens of cubic feet, that they enter the upper rarefied layers of the earth's atmosphere at speeds varying from 8 to 50 miles per second, and that the atmosphere offers great resistance to their passage, it is not surprising that in the few seconds of their flight through the atmosphere that most of them are heated to the point of incandescence and consumed before they reach the earth.



Artist's Conception of November Meteors
November 13-14, 1866

FORTY TONS OF CORAL

by

ROY WALDO MINER
CURATOR OF LIVING INVERTEBRATES, AMERICAN MUSEUM

Reprinted from Natural History ~~Magazine~~
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GUIDE LEAFLET SERIES, No. 78
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Fantastic Growths of Coral in Weird Formations Crowd the Sea Bottom

FORTY TONS OF CORAL

The Story of the Preparation of the Immense Coral Reef Exhibit Now Under Construction in the New Hall of Ocean Life at the American Museum

By ROY WALDO MINER
Curator of Living Invertebrates, American Museum

FORTY tons of coral trees growing on the ocean floor, bathed in the crystal waters of tropic seas, three fathoms below the surface, amid waving sea plumes and schools of brilliantly colored fishes flitting between their branches!

Forty tones of coral ripped from the heart of a hundred-mile submarine forest of tinted limestone, hauled to a snowy beach, bleached, embedded in sponge clippings, packed in huge crates, and shipped to the American Museum!

Forty tons of coral rising from the floor of the Hall of Ocean Life, their serrated branches interlaced as of old and once more invested with the delicate hues that gave them their pristine beauty, while above them again spreads the mirroring quicksilver of a simulated watery surface overarched by the blue of a painted tropic sky!

Such, in brief, is the story of the great Bahaman Coral Reef Group which, for several years past, gradually but steadily, has been approaching realization in the largest and most imposing of the Museums's exhibition halls. The expeditions which secured the specimens and other data for the group, replete with romance and adventure, have been described in previous issues of NATURAL HISTORY. It is not my purpose in this article to repeat these incidents in detail, but, though the exhibit, which is their fruit, is not yet completed, it may be of interest to summarize briefly the chief events of these voyages and then to recount the principal steps in the actual building of the group itself, an undertaking of unusual magnitude.

The idea of building a replica of a Bahaman coral reef had been in my mind

for a number of years, but first took definite shape during the year 1922 when the steel structure for the new Hall of Ocean Life was in process of erection and I was informed by President Osborn that the department of lower invertebrates was to have an important share in the exhibits to be housed in it. At the same time he requested me to submit suggestions for an invertebrate exhibit of outstanding character which also should be typical of oceanic life.

The reef-building coral polyp with its associates, has probably produced the most significant and conspicuous results of all the lower inhabitants of the seas. Its castellated structures of limestone may rise from depths of twenty or thirty fathoms to the ocean surface, and, in the case of the Great Barrier Reef of Australia, extend for more than fourteen hundred miles in length. They are dotted over tropic seas where they are perilous to vessels approaching them from without, while the difficult entrances through their submerged barrier walls, when mastered, lead to harbors of safety. Hence, they must be accurately mapped on navigators' charts. As world-builders, the coral and its associates have taken part in the construction of many oceanic islands forming the abode of men, and during past geologic ages, were an important source of the continental limestone deposits of the world.

It was natural that I should jump at the opportunity of building a coral reef exhibit for the new hall, and so, under my direction, Chris E. Olsen, modeler in my department, prepared a scale model of a proposed installation for the new group adapted to the architecture of the hall and embodying my ideas for the exhibit. This was presented to the President and Board of Trustees early in 1923 and was unanimously accepted by them, and I was authorized to prepare plans and to make negotiations for

SKETCH MODEL OF THE CORAL REEF GROUP

Designed by Doctor Miner and modeled by Chris Olsen on the scale of ¾ inch to the foot. The model represents the central portion of the western end of the Hall of Ocean Life, showing a representation of the proposed coral reef group in position

PALMATE CORAL WITH BEAM-SHAPED BRANCHES
A characteristic growth of coral under exposed condition near the surface of the sea. This ten-foot specimen was collected by B. E. Dahlgren and Herman Mueller from the Andros Reef in 1908, and was brought to New York by Joshua Slocum in his famous sloop "Spray," in which he had just returned from his remarkable voyage around the world

the necessary expeditionary work.

Four expeditions to the Island of Andros in the Bahamas were undertaken in the interests of the group between the years 1923 and 1930. The first, in December, 1923, was of a preliminary and exploratory character, in which I made arrangements for the first main trip which took place during the summer of 1924.

Early in June, I arrived in Nassau, accompanied by three artists and modelers of the American Museum staff: Messrs. Herman Mueller, Chris Olsen, and Dr. George H. Childs of the department of lower invertebrates. We allied ourselves there with Mr. J. Ernest Williamson, who generously put himself and his wonderful under-sea tube at our disposal, and with the cordial coöperation of the Bahaman Government we set sail for Andros.

Here, skirting the eastern shore for more than one hundred miles, is the finest coral barrier reef in the West Indies, and here, seated in the spherical steel submarine chamber of the tube, we gazed out through a plate glass window at a magnificent submarine forest towering above us everywhere. We made water-color sketches, instantaneous photographs and motion pictures through water so transparent that we could see one hundred and fifty feet through the weird tangle of sea growths before our vision was obscured by the luminous, pearly blue fog beyond.

Aided by diving helmets and a chain hoist mounted on pontoons, we attached chain or rope slings to the coral masses

FAN CORAL
This fragile variety (*Acropora muricata* var. *prolifera*) often is found clustering thickly on the floor of the sea outside the great forests of elkhorn, in strangely exposed positions without danger to its fairy-like beauty

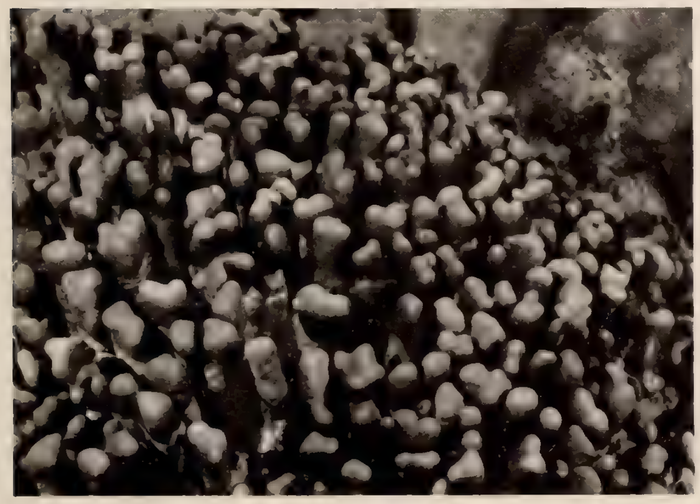
we desired, and dragged them to the surface. Our largest specimen weighed two tons and was twelve feet in length. We towed our catches to the sheltered beach of our little Cay and there we bleached them. This process consists in keeping the surface of the corals wet until the thin outer layer of animal tissue decays and sloughs off, leaving the white limestone skeleton exposed.

PALMATE ELKHORN CORAL

This beautifully symmetrical specimen (*Acropora muricata* var. *palmata*) grow in a sheltered position, so that its branches spread out evenly in broad fronds, contrasting sharply with the twelve-foot specimen shown on page 378 which grew in an exposed position on the outer reef, in which case the most rapid growth is with the direction of the prevailing oceanic currents

When we had completely covered the beach with gnarled and twisted branches of elk-horns, spike-like tangles of stag-horns and the delicate and fragile clusters of fan corals standing out among dome-shaped specimens of orb and brain corals, we sent natives to Nassau to bring us boatloads of heavy pine timber, from which we constructed crates and packed our specimens in them, embedded in sponge clippings. These were finally shipped safely to New York.

The third expedition was devoted to obtaining the reef fishes for the group. It was conducted with the coöperation of Mr. John S. Phipps, who lent us his fine houseboat yacht, "Seminole," and several smaller motor boats. The seagoing motor launch, "Iolanthe," was also with us during part of the time. Mr. Phipps' son, John H. Phipps, accompanied the expedition, and was in general charge of the fleet. Mr. Phipps, Senior, and several members of his family and guests visited us while at work. I was accompanied by my wife, son, Roy W. Miner, Jr., Chris Olsen of the Museum modeling staff, and Mr. J. L. Jaques, Museum artist. We were on the Andros Reefs from the latter part of June until



FINGER CORAL

This species (*Porites clavaria*) grows so prolifically that it sometimes rises in dome-shaped colonies thirty feet in diameter. The finger-shaped branches are closely set. A detail of the Coral Reef Group

THE TWO-TON CORAL SPECIMEN IN PLACE
This immense coral tree rises from a contorted cluster of trunks and now dominates the entire summit of the stony forest forming the center of the group. This specimen, with branches spreading twelve feet horizontally, was torn from the sea bottom in front of the coral barrier reef at Andros

the end of July. We set fish traps among the reefs, and used granges, gill nets, hand nets, and hook and line to obtain our specimens.

As soon as the fish were caught, living specimens were placed in aquaria and sketched in colors by Mr. Jaques before their brilliant hues faded. These and other specimens then passed through the hands of Mr. Olsen and my son who constructed plaster molds from them, and the specimens themselves were preserved in alcohol and formaldehyde for future reference.

In this way we secured molds and sketches of sixty-five different species of typical reef fishes. Later on, wax casts will be constructed from these molds, which, colored from the data furnished by Mr. Jaques' accurate sketches, will bring to life once more in the Museum group the multitudinous gaily colored fish population of the Andros Reef. During this expedition, Mr. Jaques made sketches for the cyclorama to form the great above-water background of the future group.

During our stay we experienced a severe hurricane but came through without damage to ourselves or our collections, and reached New York just in time to escape the second hurricane of that year which wrought such havoc in Miami.

The fourth trip was undertaken during the early spring of 1930, when Mrs. Miner again shared my experiences with me. We spent the month of March as

MAKING THE SKETCH-MODEL FOR THE CORAL REEF GROUP

Chris Olsen is modeling the coral specimens in minature under Doctor Miner's direction. They are placed in their correct position in the model; measurements are taken with reference to fixed points; and then the massive corals of the real exhibit are hoisted into exactly corresponding positions guided by similar measurements in the large group

LOOKING OVER A PART OF THE FORTY TONS OF CORAL

It took six months to clean the specimens in preparation for coloring. Those shown here have received a thin coating of wax, colored to simulate the living animal tissue covering the corals in life

MODELING "DEAD CORAL" ARCHES OVER STEEL WORK
Plaster of Paris over wire screening is used for this purpose. Later on a thin coating of beeswax and oil colors gives the surface effect of the natural formations as they appear on the sea bottom. The steel worker is constructing steel supports

ELKHORN CORAL
This unusually perfect specimen shows the typical method of branching

guests of Mr. and Mrs. Daniel Bacon on their interesting island camp, "Pirates' Nest." Through their courtesy, we established our headquarters here while gathering and preparing sea plumes and sea bushes for the new group.

Later on, we were joined in Nassau by Dr. and Mrs. Charles J. Fish, of the Buffalo Museum of Science, and with them explored the beautiful coral reef at Rose Island. This work was greatly facilitated by Mr. Hugh Matheson, of Coconut Grove, who put his ketch, the "Marmion," at our disposal. Utilizing diving helmets, we descended to the base of the reef at a depth of three fathoms, and made many observations and motion pictures of great value for the group.

So much for the field work. Difficult and arduous as it often is, and beset with unexpected and unusual problems, the work in the field is nevertheless the most romantic and enjoyable stage in the

preparation of Museum groups. More than this, however, it is absolutely essential for the production of museum groups conceived in the modern spirit.

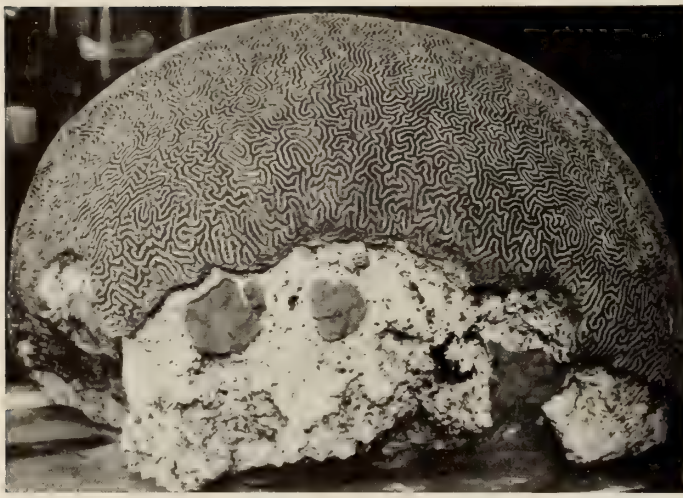
The ideal museum group is not merely a work of art. It is a record of living beings in their natural state and environment, depicted in their proper relations to their surroundings, and emphasizing the truth that the real unit in nature is the association rather than the individual.

To make these groups accurate portrayals of reality, the modern Museum finds it necessary to send out well equipped expeditions to all parts of the world to gather the facts of nature at first hand. Consequently, if it is desired to build a group which will faithfully depict the life of the sea bottom, one must descend to the bottom of the sea to obtain the material and the observations to make this possible.

The preparation of the group in the

A DETAIL OF THE GROUP
Showing the steel framework anchoring a specimen of elkhorn coral in position

BRAIN CORALS GROWING AT THE BASE OF DEAD CORAL BEAMS
Welded together by overgrowths of *Lithothamnion*, a calcareous alga, or sea plant, which encrusts the dead coral with an overlying blanket of additional limestone, thus adding materially to the bulk of the reef



A LARGE HEAD OF BRAIN CORAL (*Mæandra cerebriformis*)
Showing the intricate pattern produced on the surface of the coral limestone built up by the rapidly dividing coral polyps

Museum, while not so romantic as the field work, nevertheless is full of interest and is beset with fascinating problems. Often these present special difficulties involving original and unprecedented methods, which, however, give greater zest to the work. This has been especially true of the Coral Reef Group.

In order better to understand our aims, let us first try to visualize the exhibit as it will appear when finished. We pass through the archway leading to the Hall of Ocean Life and find ourselves standing on the gallery surrounding an enormous hall 160 feet long and 130 feet wide. The lofty ceiling is surrounded by skylights and springs from a series of arches enclosing lunettes. These form the settings for murals depicting on one side of the hall various species of whales in their oceanic environment, and on the other, scenes illustrating the capture of whales by the old-fashioned whaling ship of bygone days. Skeletons and models of whales are suspended from the ceiling. An extensive shell collection occupies the gallery, and beneath it are caught glimpses of a series of pictorial groups illustrating the life of walruses, sea elephants, seals, and other marine mammals.

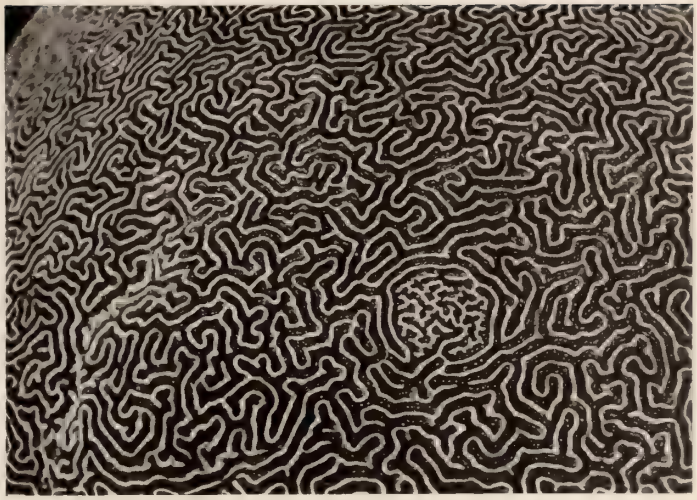
These features become apparent as the visitor has time to examine the hall in detail, but what first strikes his attention and holds his eye as he enters the hall is the enormous, brilliantly lighted group immediately facing him at the farther end.

The exhibit is framed in a great arch rising from the floor of the hall sixteen feet below the gallery and, passing through the latter, it sweeps in an enormous half-circle thirty-five feet above the main floor. Apparently one looks through the portion of the arch above the gallery into a tropical lagoon overarched by a brilliant sapphire sky with towering trade-wind clouds

TOUCHING UP THE MENDED BRANCHES
Doctor Childs is skilfully repairing an elkhorn coral specimen that was broken in transit

drifting by. In the foreground is a cay overgrown with shrubbery and plumed with wind-blown coconuts. In the distance is the long, low-lying shore of Andros.

We walk around the gallery and approach the arch from the right. The half-domed cyclorama, the masterpiece of F. L. Jaques, depicting the scene, discloses a new vista with every step. Now, we are looking out across the coral barrier marked by long lines of gleaming white breakers at the dark-blue, deep waters of the Tongue of the Ocean. As we come nearer, the emerald green shallows just within the reef meet our view, intersected with long, arching lines of rippling wavelets caused by the surges dying out over the obstructing barrier.



A "CLOSE-UP" VIEW OF BRAIN CORAL
Showing a remarkable labyrinthine growth around an enclosed nodule of more closely contorted pattern

COLORING A HEAD OF ORBICELLA CORAL
Chris Olsen is not only an expert modeler but also an artist of unusual attainments

As we face the arch, turquoise and green slicks of quiet waters spread out beyond the white, sandy point on the inner side of the cay, mirroring in the distance the alternating clouds and luminous sky colors along the horizon. Overhead, a long line of roseate flamingos sails above the palm trees, the birds lazily and majestically flapping their black-bordered wings as they follow the direction of the wind toward Middle Bight, an inland sea piercing the distant land-mass with its quiet waters.

Glancing downward, we see that the foreground is of transparent glass simulating the water surface, through which penetrate the tips of submerged elk-horn corals. We are looking into the heart of a coral reef, the treelike growths giving us glimpses of a fairy world between their branches. Our curiosity whetted, we note there are descending staircases on either hand. Down one of these we pass beneath the gallery and find ourselves looking through a coral forest, the tangled branches of which rise above our heads. We are standing on the floor of the sea!

THE STEEL FRAMEWORK OF THE "CORAL CAVE"
The heavier channel irons form the main structure and the lighter framework gives shape to the outline of the submerged coral cliffs, shown in nearly completed condition on the opposite page

I shall leave a further description of this weird and strangely beautiful world until the group has reached its completion. At the present time we are still struggling with the problems of partial accomplishment, and our imagination has filled in the unfinished details, as we are continually doing in the actual process of preparing the group. Let us now review some of the steps which have brought it to its present stage of preparation.

Let us imagine we have just returned from the expedition of 1924. Our forty tons of coral have arrived. In the courtyard outside the Hall of Ocean Life are thirty-one huge cases of hard pine. Our men carefully remove the planks from the tops of the cases, and disclose the soft masses of closely packed sponge clippings in which our corals are imbedded. Each case contains a large specimen blocked and braced in its center, while around it the lighter and more fragile specimens are closely packed, separated from one another by the elastic cushion of the sponges. As the specimens are laid out in long rows in the courtyard, we are delighted to find that but very few of them are broken after their long voyage of a thousand miles over a rough sea.

After all are unpacked, the next step is to clean the specimens thoroughly. There are so many of them, and they are frequently so complicated in their branching structure, that it takes six months of industrious work to accomplish this process properly.

Next, each specimen is coated with a thin layer of beeswax to simulate the animal layer, which in life invests the coral. This also serves to fill and seal the minute crevices with which coral is permeated, thus keeping the crumbling limestone dust within and furnishing a proper surface substance for coloring.

Now, each specimen is colored with oil colors, following sketches made from life. Each species has its appropriate color combinations and it is necessary that they should be faithfully represented to give

a lifelike appearance. Some of the brain corals are peculiarly difficult, for three main colors are involved, one of which, a green hue, must be applied in the bottom of the sinuous winding valleys with which the huge heads are covered in a most complicated pattern.

LOOKING INTO THE HEART OF THE CORAL CAVE

A detail of the group in an advanced state of completion. The cave shows in the center of the picture, its entrance overarching a projecting shelf of sage green brain coral (*Mæandra*)

Some of the delicate fan corals were quite broken, and these had to be mended. All the broken tips had to be saved and carefully matched to their proper stumps, drilled and pegged with wire pegs, cemented with litharge, and the joints colored so that they could not be detected when finished. This was accomplished most successfully, Doctor Childs and Bruce Brunner showing an especial aptitude for this work, while the coloring by Mr. Olsen and Mr. W. H. Southwick is remarkably true to nature.

Meanwhile, Olsen busied himself in constructing miniature models of each essential coral mass on the scale of three-fourths of an inch to a foot, and these were built up into a miniature composition according to the design which I had projected. This gave us a working model. Fixed points were designed upon this model and corresponding points were plotted in the great space 30×16×16 feet which the grup was destined to occupy.

A skilled iron-worker was assigned to our work, and began erecting a sloping steel framework in the form of a grid, to hold our heavy but fragile corals.

The largest coral masses were suspended by powerful chain-hoists in their proper places above this, using the sketch-model strictly as a guide. Each was carefully adjusted in a lifelike position, with due regard to the growth of each branch as determined by the prevailing oceanic currents, and then the steel structure was built up to support it properly, each piece, whether I-beam, channel iron, or T-iron, being carefully cut to fit.

It was always a case of try and cut and try again, bending and fitting according to need, remembering always the over-

PREPARING THE HUGE TWELVE-FOOT SPECIMEN
The artists are mending and touching up the coral branches, while the iron worker is working with an electric drill on the supporting steel armature

support our forty tons of coral in its proper anchorage.

Early in the construction of this part of the work two huge sheets of plate glass were raised into place to serve finally as translucent backgrounds. One of these is eleven feet in height and the two are together so contrived as to form a continuous backing for the group. On these finally will be painted a continuation of the submarine vista. A great curving opaque background behind them will depict the still more distant prospect. This will be illuminated by soft, concealed lights which, shining through the translucent screen in front, will give the soft, watery effect of the under-sea. Chris Olsen has been painting many studies of submarine effects most successfully in preparation for coloring these backgrounds.

hangs and caverns planned in the composition of the group, and yet compensating by braces judiciously placed according to need, or concealed rods bolted into the floor to act as check reins with turn-buckles adjusted to give the right tension.

This was a steel structure which no blue-print could map out beforehand and required the most continuous impromptu exercise of engineering ability and adaptable ingenuity, qualities for which Louis Beauvais has shown especial capacity during the three years in which he has been patiently fitting six tons of steel parts into this group with which to

The principal mass of coral trees rises in the left center of the foreground, the steel supports completely concealed by modeling representing eroded masses of dead coral branches forming arches and caverns.

To the right of the group a great cavern of eroded and welded limestone and coral has been modelled. This reaches the surface to form a cay of grotesquely eroded rock awash at low tide. These features have been modeled over the iron framework by Mr. Olsen, using first a base of stiff wire screening,

over which is spread plaster of Paris mixed with excelsior, forming a rigid matrix. Over this, in turn, is brushed a layer of bees' wax to form a finished surface, and finally the whole is colored with oil colors to represent dead coral limestone, coated with encrusting algæ, bryozoa, sponges, and other living forms of beautiful color tones, as in the actual reef.

Thousands of smaller and more delicate corals have been colored to be inserted at the proper time. Hundreds of sea fans, sea plumes, sea bushes, and sea whips have been prepared by special processes and colored, ready for placing. Our skillful glass-modeler, Herman Mueller, is constructing fragile glass polyps and other organisms for assembling in the foreground. Olsen is coloring, modeling, and assembling assorted varieties of details, and is devoting his ingenuity to the solution of all kinds of problems. Great sheets of rippled glass have been prepared, and a complex yet unobtrusive structure has been contrived to support them in such fashion as to simulate the water surface.

A carefully worked out system of light boxes with special illuminating units of daylight lamps is being installed, and two immense glass fronts are being ordered to enclose and protect the group both above and below the gallery.

Within the coral forest beneath the crystal water-surface, hundreds of reef fishes of all the typical species will be seen disporting themselves between the branches or darting in and out of the coral arches and caverns. These, as above mentioned, will be cast in wax, from the plaster molds made from actual fishes in the field, and colored to the verisimilitude of life.

Finally, it is hoped that the group, when finished, will create in the visitor the illusion that he has actually descended beneath the tropic seas—that, without leaving the metropolis, he has been able to witness a world of life that would otherwise require long voyages, special equipment, and the willingness to don diving helmet and leaden weights in order to lower himself into Davy Jones's Locker!

Coating the coral surface with melted beeswax

JADE

AND

THE ANTIQUE USE OF GEMS

By HERBERT P. WHITLOCK

Curator of Minerals and Gems, American Museum

Reprinted from Natural History Magazine for July-August and September-October, 1932

GUIDE LEAFLET SERIES, No. 79

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THE ANTIQUE USE OF GEMS

The Appeal of Color and Rarity of Certain Minerals to Primitive as Well as Modern Man—Their Use as Charms, Symbols, and for Personal Adornment

By H. P. WHITLOCK

Curator of Minerals and Gems, American Museum

AMONG the ancient expressions of human culture which have been handed down to us throughout the ages, we find ample evidence that our prehistoric forebears began to appreciate the decorative value of gems and precious stones at an extremely early stage in their development.

The subtle charm that holds a Twentieth Century woman spellbound before a jeweler's window doubtless prompted Mother Eve to devise ways of hanging these vivid scraps of color about her person, and of these decorative devices which have developed into our present day forms of jewelry, the necklace is without question the most ancient. From such rough assemblages of strung-together gem pebbles as the garnets found in a Bohemian grave of the Bronze Age to the most elaborate creations of the modern jeweler's art, we can trace in unbroken sequence throughout the ages, and in most of the countries of the ancient world, the evolution of the necklace.

THE MOST PRIMITIVE NECKLACE
This small handful of rough garnet pebbles was found in a Bohemian grave of the Bronze Age. Aside from the fact that every pebble is drilled, there was no attempt to shape them into beads. (Specimen in the N. Y. State Museum, Albany)

It would be highly interesting if we could conjure up a pageant of necklace wearers of all periods and races, but since this is beyond the powers of even our modern magic, we must content ourselves with the consideration of those relics that have come down to us from the past, a handful of beads here, a tarnished and battered brooch there, all that is left to tell us of forgotten beauties whose charms they enhanced before Helen wore her star-sapphires or Cleopatra her emeralds or Mary Stuart her garnets.

Among the Germanic tribes that roamed over Central Europe half a millenium before our era, amber washed up on the eastern shore of the Baltic and roughly shaped into round beads was a standard medium of exchange. A necklace of these rude, uneven, amber lumps was found in a grave of the period of about 300 B.C., in Hallstatt, Austria. Surely it would require but little imagination to picture such a barbaric trophy as the immortal necklace of the goddess, Freyja, the famous "Brisingamen" of Norse mythology.

The Gallo-Roman inhabitants of France in the Third and Fourth Centuries A.D. were lovers of fine apparel and jewels. The necklace beads of delicately colored

ROCK CRYSTAL BEADS FROM CENTRAL AMERICA

Representing a very early stage in the evolution of the necklace. They were probably made about the beginning of our era

agate and orange-red carnelian of this period show a wide range in quality of workmanship but are, on the whole, much better shaped than those of the softer amber of the previous example. Moreover, the heavier strings, some of which contain beads as large as an inch and a half in diameter, were undoubtedly worn by men.

The agate, carnelian, and rock crystal used by these early French lapidaries may well have come from France, since these stones are to be found today on French soil.

Turning to Persia we find necklace beads, fashioned out of a number of stones, whose rough shape and lack of finish indicate an early period in the development of this civilization. From Afghanistan came the deep blue lapis lazuli, one of the earliest stones to be used by man, and here wrought into roughly angular unpolished forms, mere lumps of stone with the sides rubbed smooth. From Europe came caravans bearing amber from the Baltic which was carved into flat cylindrical beads with rounded sides, quite different in appearance from those of Central and Northern Europe. And most important and significant of all, from the ancient mines near Nishapur in northeastern Persia came the turquois which has so long been associated with Iranian culture, and which was carved into necklace beads, whose rude, thickened disks suggest those made today by the Navajo and Pueblo Indians of our own Southwest.

Almost incredibly old are the long, cylindrical beads of Chinese jade which represent one of the earliest uses to which inhabitants of the "Flowery Kingdom" put their national gem stone.

Only one civilization other than China has made use of jade for personal adornment. Necklace beads of jade, irregularly

AN EARLY PERSIAN NECKLACE

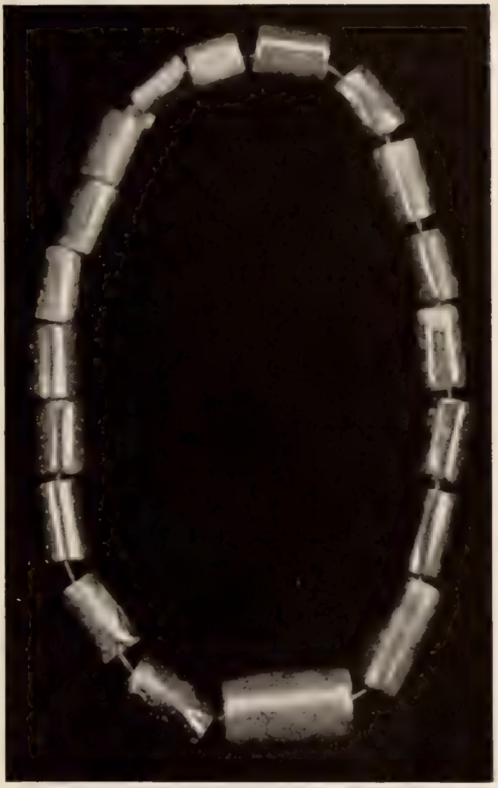
This string of necklace beads was fashioned from rough lumps of lapis lazuli, brought by the trading caravans from Afghanistan

rounded but nicely polished, have been found among the remains of the Zapotec culture of ancient Mexico which flourished at about the beginning of our era. Earlier beads from Central America are very roughly fashioned out of rock crystal, and a very recent excavation has brought to light beautiful necklace jewelry from Mexico in which brilliant, translucent, green jade has been combined with gold in a manner that would do credit to a modern designer.

In the bazaars of India, Ceylon, and Burmah, there sit today, as their forebears have sat for centuries, the East Indian gem cutters, fashioning necklace beads from the gem stones of their countries. Sapphires, rubies, garnets, a rich wealth of color go into these necklaces, the elements of which are sometimes roughly faceted, but more often of somewhat irregular rounded shape, following the time-honored custom of the East, that strives to produce the largest and heaviest gem possible from the fragment of material used.

The necklaces which have come down to us from the higher development in culture of the later Egyptian dynasties show a very considerable scope in the materials used. Amethyst, lapis lazuli, carnelian, turquois, jasper, rock crystal, garnet, and even emerald were freely combined with gold to produce bead jewelry forms of great taste and charm.

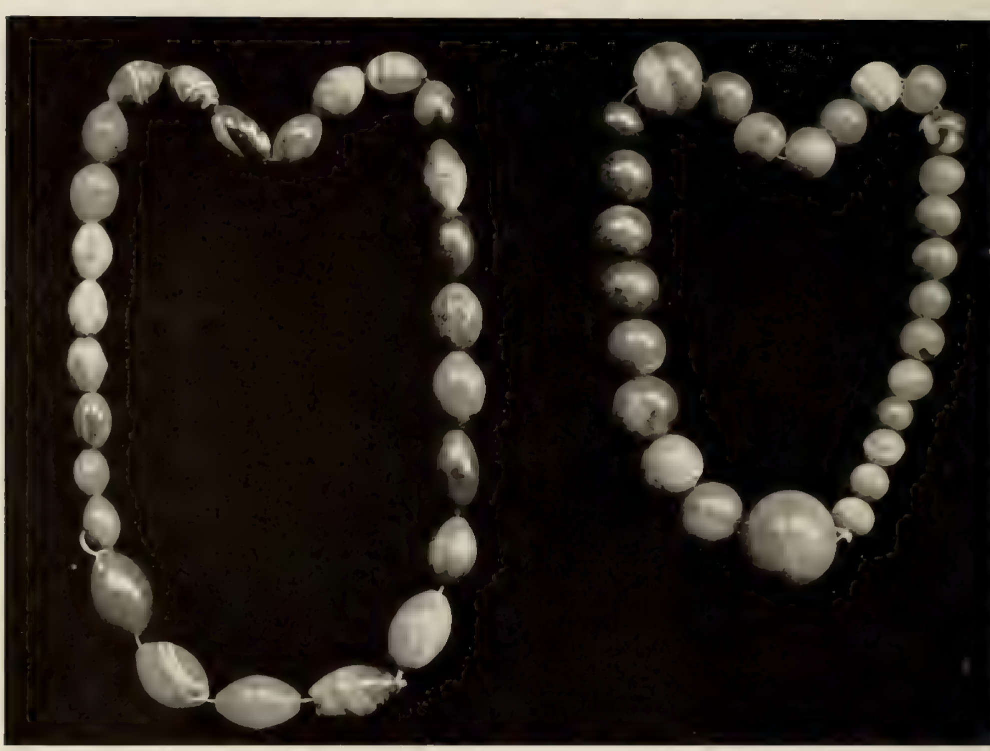
It is quite significant that Egyptian gem cutters seemed unwilling to alter such regular crystal forms as the hexagonal prism of emerald by cutting them into round or prolate beads. These forms were usually preserved intact in the bead design, and whereas the beads fashioned from amethyst, carnelian, or amazon stone were made spherical or cylindrical, the six-sided prisms of emerald were simply pierced in the direction of their axes, and left otherwise unworked.



AN ANCIENT CHINESE NECKLACE
These cylindrical beads are roughly carved from Chinese jade. They belong to the legendary past of that fascinating old corner of the Orient. (Specimen from the Drummond Gift)

The reason for this may lie in the reluctance of the artificer to waste any of the material of the rarer and consequently more precious stone, or possibly some symbolism may have been attached to its regular natural shape. At least this treatment of emerald may be observed not only in Egyptian jewlery but also in that of Cyprus and Etruria.

From the necklace composed of strung beads it is but a step to one in which the roughly shaped stones were encased in a metal setting. In Egypt we find this advance taking place at quite an early stage, as instanced by an example in the collection of the Metropolitan Museum of Art, where a small, square plaque of gold enclosing an oval carnelian forms the middle element of a double string of *unset* carnelian beads.



TWO NECKLACES OF AGATE

The Gallo-Roman people of France in the early centuries of our era fancied agate for their necklaces, some of the heavier of which were worn by men. These two come from the Department of Gard in Languedoc

From very early times until approximately the period of Ptolemaic kings we find the Egyptians making use of a sort of mosaic of gem stones, turquois, and lapis lazuli, set in thin gold boxes, the latter being shaped to the design so that, when the whole was polished, it had somewhat the aspect of the cloisonné work of Russia.

The transition from such primitive combinations of gem stones with the precious metals, to the more elaborate settings of Greece, Rome, and the later cultures of Europe and Asia is both easy and obvious, and once made, the development of jewelry forms was simply a matter of that artistic progress which follows so closely upon historic and political progress. As the needs of an ever advancing civilization called for more and more varied ornamentation of dress and person in gold and silver, it was inevitable that these ornaments should be embellished with gem stones that had already became familiar to man through the medium of earlier and simpler jewelry forms.

A striking instance of this adaptation of the earlier to the later usage is to be found in the necklace that constitutes the ceremonial trapping of a Vizier of Morocco of the middle of the Eighteenth Century. The roughly rounded aquamarines that furnish the larger jewels for the medallion settings that constitute this regalia are pierced, clearly indicating that they were once strung together to form a necklace of beads of a much earlier and more primitive type; how much earlier we can only conjecture.

The use of various minerals as materials from which objects for personal adorn-

ment were made, ancient though this use is, does not constitute the only, nor even the most deep-seated side of the question of the antique use of gems. It is safe to assume that from the very earliest period, when people began to recognize the beauty of certain stones, they also began to ascribe to them certain supernatural properties as amulets and talismans. And as far back as we can trace, they wore some material token in the form of a stone to guard them from the ills of life, real or imaginary. The wearing of such amulets is, in all probability, older than the wearing of jewelry, and, no doubt, the one grew by insensible steps out of the other. It was essentially a natural and logical act for the primitive man who found an

BEADS OF DEEP, FIERY, INDIAN GARNETS
The necklace beads cut by the native gem cutters of India, Burmah, or Ceylon have a character of their own

attractive or unusual bit of stone to ascribe to it occult powers. As he advanced in culture, he shaped these bits of stone into increasingly regular forms, and finally as an added fetish, he scratched on them images of his gods and invocations to them. A talisman was supposed to be endowed with wider and more general powers than was an amulet, the function of the latter being to ward off evil. The addition of a magical combination of words would make either a talisman or an amulet a "charm."

DEEP BROWN COPAL BEADS
The natives of the west coast of Africa, the country of "Trader Horn," made and wore this necklace of copal, which was their substitute for amber

Some of the earliest amulets of which we have any knowledge are the little stone cylinders that were used among the Assyrians, Babylonians, Persians, and Hittites, as seals. These cylinders, some of which date as far back as 4000 B.C., are carved from various minerals, such as steatite, serpentine, hermatite, lapis lazuli, jasper, amazon stone, chalcedony, marble, and rock crystal. Many of these materials

are esteemed today for their beauty as mediums for small carvings, proving that modern taste in this matter is at least founded upon ancient precedent.

The engraving was of course incised, both because this was the easiest and most obvious way of engraving hard materials, and because the impression made by rolling such a seal over a suitable soft substance was more natural and more easily read.

Considerable skill was displayed by these early lapidaries in cutting their designs, which included figures of gods, men, and animals, as well as inscriptions in cuneiform characters. The inscription often gave the name of the wearer, the name of his father, and the name of his god. The significance of this sequence becomes apparent when we consider that the official name given to every man upon coming of age placed him under the protection of a god, who forthwith made his abode in the body of this particular man subject to his good behavior. But should he be so unfortunate as to sin against his fellow men or against the gods, the divine presence left him and he immediately became the prey of some one of the seven devils.

Asiatic cylindrical seals of this type were not set in rings as are those of our day, but were hung around the neck, or fastened on the arm. A typical example of a Babylonian cylinder from among the small but representative series in the Morgan Gem Collection, is carved from limpid rock crystal and is approximately 3000 years old. This is engraved with an image of the storm god Rammon, who was identical with the Rimmon of the Old Testament (2 Kings, v. 18). He is here represented in a short robe holding a scepter in one hand, and accompanied by his wife, Sahla, whose figure in a long, flounced dress is shown on both sides of him.

FROM NORTH AFRICA

A string of old and crudely shaped necklace beads. The pale green aquamarines which compose its elements are similar to those which adorn the large medallions in the necklace on page 9

RICH AND COLORFUL

The necklace of a Vizier of Morocco of the period of about 1750. The aquamarine gems of the large medallions have been pierced and were at one time a string of beads like that shown on page 8

In Egypt the most popular amulet was the well known scarabæus or scarab, the somewhat conventionalized image of a large black beetle regarded as a symbol of resurrection and immortality, since it was believed that no female of this insect existed. These carved beetles were engraved, as were the Asiatic seals, the inscription being cut on the oval underside of the conventionalized figure in idiographic characters.

Scarabs were even more typically amulets than were the cylinder seals of Babylon and Assyria, for although they commonly bore the name of the wearer, they were in many instances inscribed with magical charms taken from the Book of the Dead. Beautifully worked funeral or heart scarabs were often made from green jasper, amethyst, lapis lazuli, amazon stone, carnelian and serpentine, while the more precious emerald and turquois were not without representation among these figures of the sacred beetle that replaced the heart in the mummies of the Egyptian dead.

It was believed that when the soul of the deceased came to be judged before Osiris, his heart was weighed in the balance held by Anubis against his good or evil deeds in life. Consequently the charm inscribed on a heart scarab invoked the gods of the underworld to deal leniently with the heart of the dead. An example inscribed on a scarab of green feldspar would read[1]

> Oh ye gods who seize upon Hearts, and pluck out the whole Heart, and whose hands fashion anew the Heart of a person according to what he hath done, Lo now let that be forgiven to him by you.
>
> Hail to you, Oh ye Lords of Everlasting time and Eternity.
>
> Let not my Heart be torn from me by your fingers.

[1]Quoted from *The Magic of Jewels and Charms* by Dr. George F. Kunz, p. 319.

A NECKLACE FROM ANCIENT CYPRUS
Showing a charming combination of gold with agate and carnelian beads carved as turtles. This use of gold and gem stones reflects strongly Egyptian influence. (Specimen in Metropolitan Museum of Art)

EGYPTIAN OR SYRIAN NECKLACE
Of the Sixth Century A.D., Rough prisms of light-colored enamel are used as beads, alternated with pearls in a gold setting. (Specimen in Metropolitan Museum of Art)

Let not my Heart be fashioned anew according to the evil things said against me.

For this Heart of mine is the Heart of the god of mighty names, of the great god, whose words are in his members, and who giveth free course to his Heart, which is within him. And most keen of insight is his Heart among the gods.

Ho to me, Heart of mine; I am in possession of thee, I am they master and thou art by me; fall not away from me; I am the dictator to whom thou shalt obey in the Netherworld.

Among the peoples that were influenced by Egyptian culture, the scarab gradually became more highly conventionalized, losing much of its resemblance to a beetle as it lost its symbolic and esoteric significance. Thus we have the scaraboid, an oval dome-shaped seal, inscribed on the flat underside as was the scarab, but no longer with the magic charms of Egypt. In other words the scaraboid, a purely ornamental engraved stone, is literally the "stepping stone" between the scarab and the modern form of seal. A form of engraved amulet that came into use in Persia about the Eighth Century, and

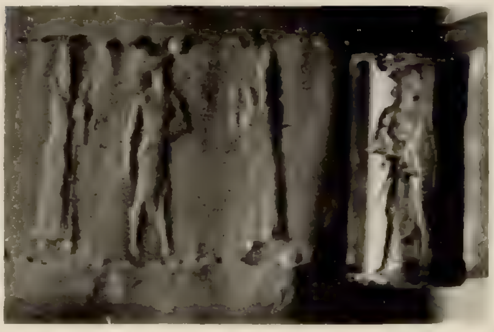
that reached its culmination in elaboration from the Sixteenth to the Seventeenth Centuries, was made from polished, flat slabs of chalcedony and carnelian, varying in size and shape, but rarely more than two and a half inches in longest dimensions. These Persian seals belonged to the Moslem culture, and since the Mohammedan code forbids the depicting of natural objects, the engravers of these amulets were restrained from using the symbolism employed by peoples of other faiths. As a consequence they all bear texts from the Koran inscribed in Arabic characters, the engraving in many instances being beautifully executed. The quaint Arabic letters that look like some glorified kind of shorthand, are highly decorative, and were embellished with loving care by the Moslem engravers.

The smaller and older examples are mostly oval or more rarely cushion-shaped and were lettered with incised

AMETHYST BEADS
A necklace of the early Christian Era (4th–6th Centuries) showing strong Egyptian influence. (Specimen in Metropolitan Museum of Art)

AN EARLY EGYPTIAN BROOCH
Here the design is formed by carefully shaped pieces of turquois and lapis lazuli, each set in a little box of gold. This gem mosaic was the forerunner of jewel settings. (Specimen in the Museum of the New York Historical Society)

characters often deeply cut as though for use as seals. The larger and more elaborate forms have a broad, heart-shaped outline, and are representative of the later period. In these the lettering of the central panel is very slightly raised against a matte background composed of fine crossed lines, so that the inscription stands out on a polished surface against a dead one. The surrounding border is lettered with a longer text in smaller incised characters.



A CYLINDER SEAL
Carved from rock crystal in Babylon about 2000 B.C. At the left is shown the impression made by rolling the cylinder over a piece of soft clay

Nothing can be more appealing than the exquisite delicacy and detail of this engraving as revealed when the light strikes across the polished face of the lettering. The effect is much the same, and achieved in the same way, as that which one sees on an old engraved sword blade.

It is quite frequent among the engraved chalcedony amulets of both the oval and the heart-shaped types to find a short text, or sometimes only the name of the Prophet, occupying the center of the design, and a longer text wrought as a border or panel around it. Also we meet with considerable repetition, a text of notable efficacy as a charm being used on many amulets. Here is one from one of the later seals, now a part of the Morgan Gem Collection.

CENTER: And the Thunder declares His Glory with His Praise, and the angels also for awe of Him.

BORDER: In the name of Allah, the compassionate, the Merciful. Allah is He besides whom there is no god, the Everliving, the Self-subsisting by whom all subsist. Slumber does not overtake him nor sleep. Whatever is in the Heavens, and whatever is in the Earth is His. Who is he that can intercede with Him but by His permission? He knows what hath been before them, and what shall be after them, and they cannot comprehend anything out of His knowledge except what he pleases. His knowledge extends over the Heavens and the Earth, and the upholding of them both burdens Him not. And He is the most high, the great.

A PERSIAN AMULET
Carved from chalcedony and engraved with texts from the Koran. The Arabic lettering has the effect of an intricate and beautiful decoration.

A notable exception to the almost universal use of quartz for these Moslem seals, is an irregular slab of turquois in the Morgan Gem Collection, five inches by three, engraved with about two thousand words.

DRUMMOND GIFT COLLECTION

THE FIVE HAPPINESSES

JADE

The Mythology and Symbolism Expressed in the Carvings of the Jewel of Heaven

By HERBERT P. WHITLOCK
Curator of Minerals and Gems, American Museum

NEARLY twenty-four hundred years ago Confucius, speaking of the "jewel of Heaven" said, "In Ancient times men found the likeness of all excellent qualities in jade."

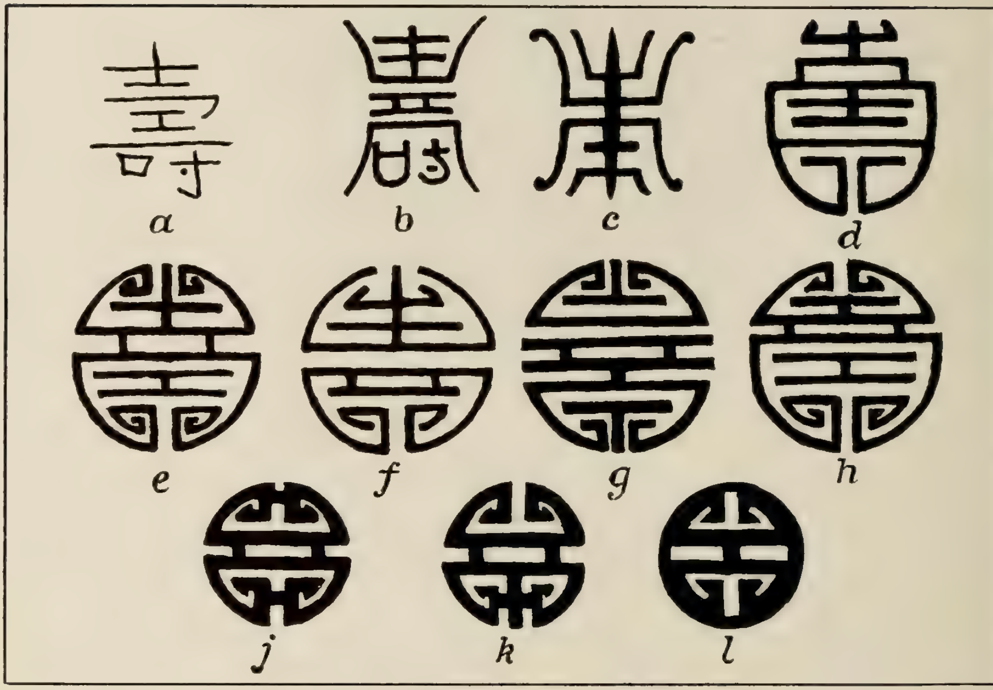
Perhaps nothing can so vividly present to us the remote antiquity to which we must turn to find the beginnings of Chinese carved jade than the words "in ancient times" from the lips of this old sage. And it may not be amiss for us to enquire into the questions of how and why these orientals should regard this stone as the embodiment of all virtues.

Under the general term "jade" are included massive varieties of at least two mineral species,—a massive pryoxene known as jadeite, having the composition of a soda alumina silicate, and a tough, compact amphibole, called nephrite, and corresponding in composition to a lime magnesia iron silicate. So closely do these mineral materials resemble each other in texture and outward characteristics that it is often difficult to distinguish them apart, especially when carved.

A FINGERING PIECE

Of white jade, in which a brown-colored area has been used for the ears and face of the "happiness" bat. The bulk of the piece represents a bag of grain (for prosperity). Below the bat may be seen the cords which tie the mouth of the bag. The whole carving is wonderfully smooth to the touch. Whitlock Collection

Of the two, jadeite is slightly the harder, having a hardness of 7 in the Mohs scale as compared with about 6.5 for nephrite.



THE CHINESE CHARACTER MEANING IMMORTALITY

With some of the conventionalized variations (Sho marks). *a* Written character. *b* From an old embroidered silk. *c* From a suit of armor of the imperial guard. *d* From a jade wine pot (Tang dynasty). *e–h* Variations mostly in raised carvings on jade. *j, k* From jade pendants (K'ien Lung period). *l* Movable pivot from a jade prayer wheel

Also the specific gravity of jadeite is rather higher than that of nephrite; 3.34 as compared with about 2.95–3.00.

By reason of its toughness and relative hardness, jade was a favorite material for the fashioning of implements employed by primitive man. Wherever jade was obtainable, either from a native source or through trade, we find men of the cultural stage corresponding to the late Neolithic era employing nephrite, and occasionally jadeite, as materials for celts, axes, and other primitive tools and weapons, much as the natives of New Zealand at present make use of their local nephrite. But, although such jade implements of early man have been found in many places throughout the world, there are but two regions where the use of this material has risen in cultural degree from the purely utilitarian to the decorative stage that places it among the ornamental stones.

WHITE JADE CARVING REPRESENTING THE IMMORTAL WARRIOR CHUN T'I RIDING ON THE ONE-EYED PEACOCK. WHITLOCK COLLECTION

In the portions of the tropical Americas comprising Southern Mexico, Yucatan, Guatemala, Costa Rica, Panama, Colombia, and possibly Ecuador and Peru, the pre-Columbian cultures furnished many carved jade objects of decoration well within the scope of ancient jewelry. There are now no known deposits of either jadeite or nephrite in these countries, and at the time of the conquest of Mexico by Cortez, jade was so rare and so highly esteemed by the Aztecs that it

constituted their most precious possession, worth many times its weight in gold.

It is, however, among the Chinese that the high estimation of jade places it above all other gem stones. And it is in China that we find the use of jade not only extending back into vast antiquity, but furnishing us with a means of tracing through the countless examples of both ancient and modern carved objects the development of a highly interesting and attractive expression of the lapidary art.

A GIRDLE PENDANT CARVED FROM WHITE JADE SHOWING THE IMMORTAL CHANG-KUO, RIDING HIS MAGIC COLLAPSIBLE MULE. WHITLOCK COLLECTION

As far back as the period of the Chow dynasty of the Eleventh Century B.C., we find nephrite used for carved designs, decorated chiefly with geometric motives.

Although jade of this early period was originally of some shade of green, corresponding to nephrite as we know it today, the green color has, in many instances been altered to some shade of brown, ocher, or dull red. This change is purely superficial, affecting only a very thin layer of the surface, and is due to the action of the weather during long periods of time, the iron oxides, which originally colored the stone green or grayish-green, having been replaced by higher oxides of the ocher or umber shades. Since the oxidizing agencies producing this surface change of color are those that operate best in the upper layers of the soil, it follows that jade pieces which have been buried for long periods of time exhibit it in the highest degree.

A FIGURINE REPRESENTING KWAN YIN, THE GODDESS OF MERCY, CARVED FROM DARK-GREEN YUNNAN JADE. AMERICAN MUSEUM GEM COLLECTION

Nephrite from local sources in Shensi and other Chinese provinces, or brought from Eastern Turkestan, or possibly from a deposit near Lake Baikal, furnished most of the jade of this period. In color the stone from these deposits varied from white and gray-green, through leaf-green to dark laurel-leaf-green, the depth of color increasing with the amount of iron contained in the nephrite. Some jadeite from Shensi and Yunnan provinces of China, and from Tibet was no doubt also used for Chow carvings, as for the worked jade of later periods. It is however, difficult to separate the jadeite of this culture from nephrite on a basis of color alone, particularly as many of the carvings in both materials have been altered in color through having been buried.

The tendency to supplant the geometric formality, characteristic of early jade carv-

THE FIVE POISONS

An amulet carved from white jade, representing a toad, a serpent, a spider, a lizard, and a centipede, the five venomous creatures whose images protect from evil. Whitlock Collection

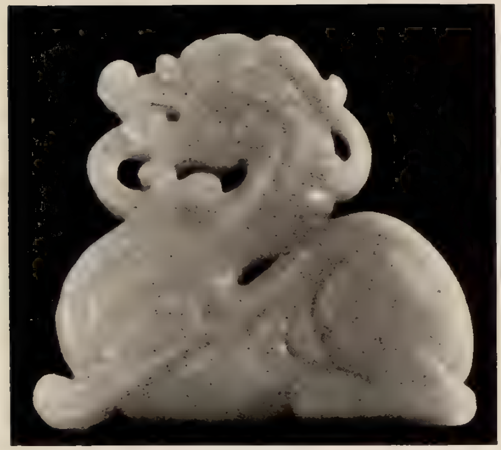
ing, with a freer and more graceful ornamentation culminated in the highly elaborate carving of the K'ien Lung period (1644–1912), with its undercut relief and openwork patterns. At this time also the beautiful green jadeite, from the Mogaung district in Upper Burmah, began to be imported into China, and much enriched the materials available for Chinese expression in carved jade. This choicest of the jade varieties is also the best known to the western world under the name of "imperial jade." It is never found in large masses, always in relatively small areas disseminated through white jadeite which fact accounts for the mottled and streaked distribution of color observed even in some of the finest and most highly prized pieces.

Aside from the semitransparent apple-green of the imperial jade, the colors that characterize this ornamental stone run the gamut of tints from the translucent white of "melting snow" or the more opaque "mutton fat" varieties through various shades of green, to deep "spinach"-green heavily mottled, and even to the black of *chloromelanite.*

Among the rarer colors may be ranked the light ocher yellow of some Burmese jadeite, a blood red, met with in patches in white jadeite, and a still rarer light violet or mauve. A beautiful jadeite from Yunnan province is colored a mottled, opaque, grass-green, very much

WHITE JADE DISK REPRESENTING THE MOON

The white rabbit, symbolizing the *Yin* principle, is compounding the pills of immortality in a mortar. Drummond Gift Collection



A DRAGON
A white jade figurine of a dragon with somewhat lion-like proportions. Whitlock Collection

like the color of malachite, but differing from the latter stone in texture.

With increased elaboration in the carving of jade by the Chinese lapidaries there grew up a symbolism involving the subjects depicted in this art. Just as among more primitive people we find glyptic artists depicting gods and heroes, sacred animals and supernatural attributes, so among the Chinese carvers of jade we find myth and legend, philosophic principle and ritualistic symbols used freely and developed with increasing conventionalization as the forms and patterns were

A HORNED AND WINGED DRAGON
Intricately carved belt ornament of white jade. Note the elaborate pierced carving in the background. Drummond Collection Gift

handed down through many generations of artists.

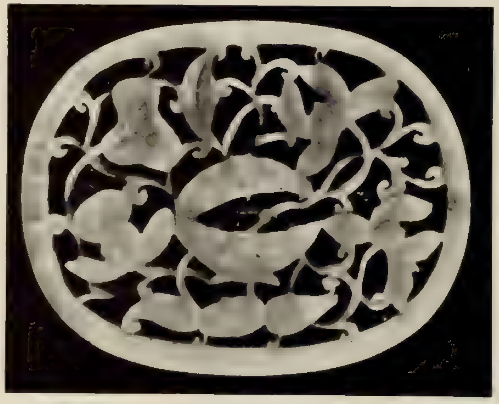
To those of us who have seen large assemblages of Chinese carved jade a very familiar figure is that of a tall, graceful woman, represented seated or standing, and holding either a vase or a lotus flower in her hand. She is Kwan Yin, the Goddess of Mercy, one who hears the cry or prayer of the world. According to the beautiful legend of the Chinese Buddhists,

DRAGON, HIGHLY CONVENTIONALIZED
Carved in old jade; of the period of the Chow dynasty. Note the archaic square turns of the body and the birdlike head substituted for a tail. Drummond Gift Collection

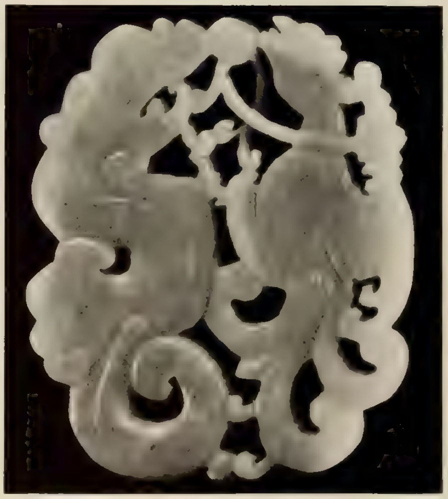
she was about to become an immortal, but turned back from the very gateway of the Western Paradise, when she heard a cry of anguish rising from earth. So by renunciation she achieved immortality in the hearts of the sorrowing throughout the centuries. Her shrine and her image is to be found in every Chinese temple, as

her prayer is always on the lips of countless mothers: "Great mercy, great pity, save from misery, save from evil, broad, great, efficacious, responsive Kwan Yin Buddha."

Whenever one finds six little men and two women carved in jade be sure that they are the famous Eight Immortals of Taoism. These legendary characters probably at one time actually lived, at least we have excellent reasons to regard some of them as historical personages. According to very old Taoist legends all of the Eight became immortal and each may be recognized by some article that he or she wears or carries, as the crutch and gourd full of magic medicines of Li T'ich-Kuai, or the magic feather fan with which Chung-li Ch'uan fans the souls of those who are to be immortalized back into their bodies. Some of the Eight Immortals are depicted alone, as Chang-Kuo who is shown seated on his marvelous donkey, which folds up like a piece of paper when not in use, and his bundle of magic rods, with which he wrought all manner of necromancy.



THE LOTUS
An open carving in white jade showing the lotus, one of the "eight auspicious signs," growing from a vase formed from one of its own pods. Whitlock Collection



WHITE JADE GIRDLE PENDANT
Representing a conventionalized dragon on the left, and a phœnix on the right. Both embody the *Yang* or male principle, and in this design support the disk of the sun. Whitlock Collection

Chinese legend relates that long ago in the nebulous period that preceded the Chow dynasty there occurred a tremendous battle of the Gods in which demigods, Buddhas, and Immortals, not to mention fire dragons and other wonderful creatures, participated. It was an epic struggle, a sort of Chinese Siege of Troy or Mahabharata in the course of which Chun T'i, a Taoist warrior much gifted in magic, transformed his adversary into a red, one-eyed peacock upon whose back he rode through the sky to the Western Paradise. A little jade carving, no larger than a half dollar depicts this episode with detail and fidelity, even to the single eye of the peacock.

Disks of white jade sometimes show carved in relief a rabbit standing on its hind legs beside a conventionalized tree, engaged in pounding something in a mortar. The subject of this design emanates from the legend of Heng O, the wife of Shen I, the divine archer. She ate one of the pills of immortality and flew to the moon. Seized with a violent fit of coughing, she presently coughed up the coating of the pill she had eaten, which immediately became a rabbit as white as purest

jade. Thus was created the ancestor of the *yin*, the negative or female principle of universal life, whose prototype is the moon.

The essence of the *Yang* or male principle resides in the person of the dragon, that mythical animal or being endowed by the Chinese mind with supernatural powers which are generally assumed to be exercised for good rather than evil, as when a dragon was invoked in times of drought to bring fertilizing rain. In this sense dragons were looked upon as veritable deities, and according to Berthold Laufer[1] the manifold types and variations of dragons met with in ancient Chinese art are representative of different forces of nature, that is, of different deities. In a measure this would explain why dragons are so universally represented in jade carvings, and why they vary so richly and amazingly. Some are full-bodied like lions, while some are attenuated, convoluted, and very reptilian indeed. Some have branching horns and others are decorated with manes that are singularly like human hair. An old Chinese classic ascribes nine "resemblances" to the dragon; its horns are like those of a deer, its head that of a camel, its eyes are those of a devil, it has the neck of a snake, the abdomen of a cockle shell, the scales of a carp, the claws of an eagle, the soles of its feet are like those of a tiger, and its ear like those of an ox. Even in the matter of claws this miraculous beast holds to no fixed rule for, although the imperial dragon has five to each of its four feet, ordinary dragons have but four.

Perhaps because of the fact that Chinese designs and decorative motives

[1] "Jade: A Study in Chinese Archæology and Religion." Field Museum of Natural History Publication 154, 1912.

A GROUP OF "WHEELS OF LIFE" CARVED IN WHITE JADE

Two have movable centers and can be rotated by holding the loose central piece between thumb and forefinger. The other one has a swastika for a center. Whitlock Collection

have been handed down from very ancient times, Chinese artists have learned to express these designs in highly conventionalized treatment. In no instance is this more obvious than in the treatment of the dragon in carved jade. His sinuous body has taken on angular bends or perhaps more frequently has divided and branched like a heraldic mantle. His feet have disappeared, or where present, the toes sometimes spread like the spokes of a wheel, the claws joining on to each other in a circle. Often a dragon holds or supports a round object like a pearl, which really represents the sun, phototype of the *Yang*.

A SYMBOL OF IMMORTALITY
Highly conventionalized butterfly carved from white jade

Often associated with a dragon in designs of carved jade, is the phœnix, a highly conventionalized bird which ordinarily symbolizes prosperity. The phœnix, however, also stands for passionate love and is consequently an appropriate and symbolic love gift.

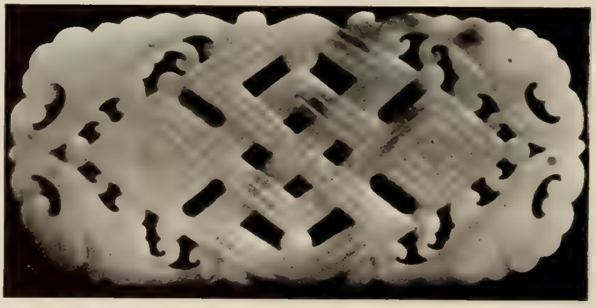
Much the same symbolism is attached to a pair of fishes or carp, whereas one carp often stands for power or literary eminence. Chang Tao-ling, who may be considered the actual founder of modern Taoism, is represented as riding on a tiger under whose paw are crushed the five venomous creatures: the lizard, snake, spider, toad, and centipede. Sometimes these five are represented together in carved jade in an amulet known as the "Five Poisons."

TWO AUSPICIOUS SYMBOLS
A peach blossom, also symbolic of immortality has been made a part of this butterfly design

When Buddhism was introduced into China from India in the Han dynasty in the first century of our era, it brought with it a very interesting series of symbols, known as the "auspicious signs," most of which were said to have been stamped in the footprint of Buddha. These Buddhist symbols were favorite forms among the lapidaries of the Kien Lung period, and are often met with carved in white jade of that epoch. One of the most characteristic of them is the Wheel of Life, a disk represented within a disk, often

THE MYSTIC KNOT

A very popular Buddhist symbol, carved as a buckle in white jade



Note the swastika in the center of the closed loops. Whitlock Collection

wrought with a very cleverly executed movable center about which the whole device may be turned. In this way we have the so-called "prayer wheels" dear to the hearts of Tibetan Buddhists in whose reverend fingers they revolve, in a measure taking the place of the bead rosary. The "spokes" connecting the two disks may number six or eight and the design of the central movable disk may represent the swastika, or the immortality symbol, or even the mystic *yang yin.*

Another very popular auspicious sign is the lotus, either represented with its leaves, embellishing other designs, or growing from a jar or vase, the jar being yet another of the eight treasures of Buddha.

A symbol much in favor is that "mystic knot" which is represented as having no beginning and no end. Not only was this sign one of those found in Buddha's footprint, but it is also said to have appeared on the breast of Vishnu. The Chinese, who love to ascribe auspicious meaning to their symbols, sometimes call it the "Knot of Everlasting Happiness."

Returning to the Taoist type of symbols, we have the magic gourd, sometimes depicted alone and sometimes accompanied by a monkey. In the legend of the monkey that became a god this famous gourd was the prized possession of the Demons who opposed Sun Hou-tzu, the Monkey Fairy, and his master, and was capable of containing a thousand people. Sun by a clever device exchanged it for a worthless gourd, which he made the Demons believe could contain the entire universe.

Because butterflies symbolize immortality in Chinese, as they do in Greek mythology, carvings of butterflies were buried with the dead, and no doubt the beautiful white jade butterflies of the K'ien Lung period are survivals of a symbol handed down from Han time. Like most of the other Chinese carved forms they have become highly conventional, often with peach blossoms and swastikas represented on the extended wings.

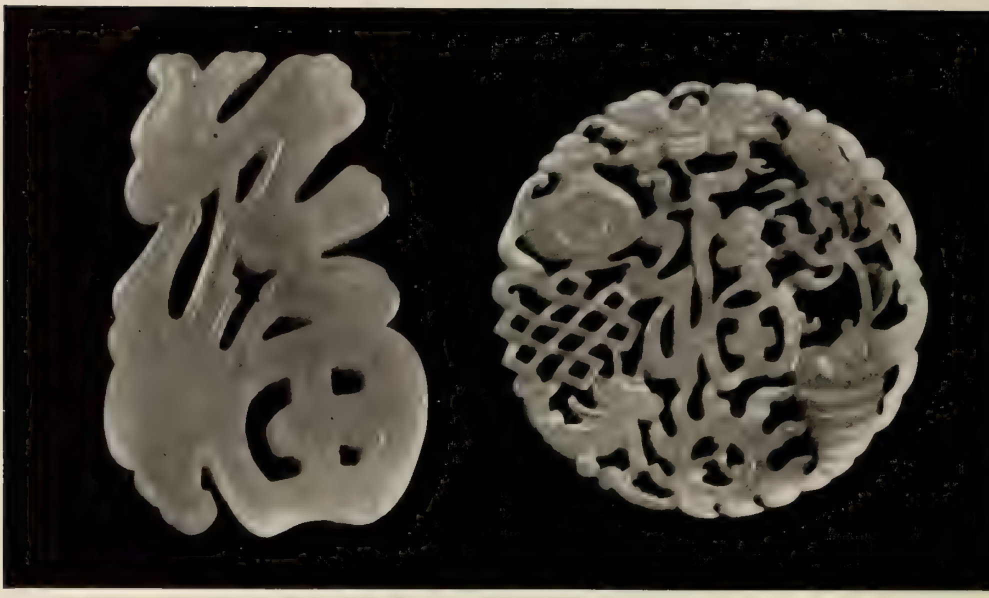
In the midst of the Western Paradise on the border of the Lake of Gems is the orchard of immortal peach trees whose fruit ripens every six thousand years. These celestial peaches have the mystic virtue

THE HAPPINESS SYMBOLS
Note the "bat of happiness" above the "happiness" character

This girdle pendant illustrates another variation of the happiness character surmounted by the bat of happiness

The simplest form of the happiness character

It is surmounted by the sun disk between dragons



WHITE JADE GIRDLE PENDANTS

Carved with the luck character. To the left is shown the character unembellished, on the right it occupies the center of the design surrounded by a gourd, a mystic knot, a sun disk, etc. Whitlock Collection

of conferring long life, and thus by eating them the Immortals renew their immortality. That is why the Peach of Immortality is so often carved in jade, and why the immortal peach blossom is such an auspicious symbol.

Almost equally auspicious as one of the magic emblems of Taoism, is the Fungus of Immortality which was supposed to grow only on the sacred mountain Hua Shan in the province of Shensi. The contorted and involved shape of this miraculous plant lends itself well to the designs of girdle pendants and it was often carved in the white jade of the K'ien Lung period.

Not only are the Chinese fond of auspicious symbols, but they love a rebus, or as we would say, a pun. The Chinese word for happiness is *fu*, and the same word pronounced a little differently means a bat. So a carved bat becomes a symbol of happiness, and is very generally used either alone or combined with other favorable symbolic designs. Should you meet a design involving *five* bats you are to read it as meaning the "Five Happinesses," that is to say "Old Age, wealth, health, love of virtue, and a natural death."

It would probably never occur to any one but a Chinese to use the somewhat complex graphic symbols of the Chinese language in a decorative way. And yet treated conventionally, as the Chinese treat all of their designs, these characters are capable of developing into balanced and well proportioned decorative forms.

One of the oldest as well as one of the most decorative of these "Sho marks" is the character that stands for longevity, or to give it a more mystic significance, immortality. The figure on page 14 shows the modern Chinese character for longevity and a series of its conventionalized variants mostly derived from jade carvings. This seems to be a favorite symbol for use as the movable center of the "prayer wheels" mentioned a few pages back.

Another character very popular with the carvers of girdle pendants in white jade is that which signifies happiness. This is, of course, often combined with

the happiness bat, as well as with dragons and other auspicious symbols. An interesting variation is the "doubling" of the symbol by representing two happiness characters side by side, adjacent parts being connected.

The jade pieces carved with this "double happiness" are appropriate gifts for newly married couples, and convey a wish that their union may be a long and felicitous one.

A somewhat rare conventionalized character in carved jade, rare because it does not lend itself readily to symmetrical design, is the one that signifies luck or good fortune. In the writer's experience it has been used either alone, without decorative embellishments, or in a somewhat haphazard assemblage of symbols.

Certain designs lend themselves specially to the smooth, rounded contours of fingering pieces, such as are dear to the hearts of contemplative Celestials, who love to sense their cool, delicious feeling through what is to an Occidental the least developed of the senses. Perhaps if we cultivated a love for jade fingering pieces we would think more. Who knows?

A Large Button or Stud Carved from White Jade with a Highly Conventionalized "Swirling" Floral Form, in the Center of which is the Famous "Yin Yang" Mark. Whitlock Collection

DIVING IN CORAL GARDENS

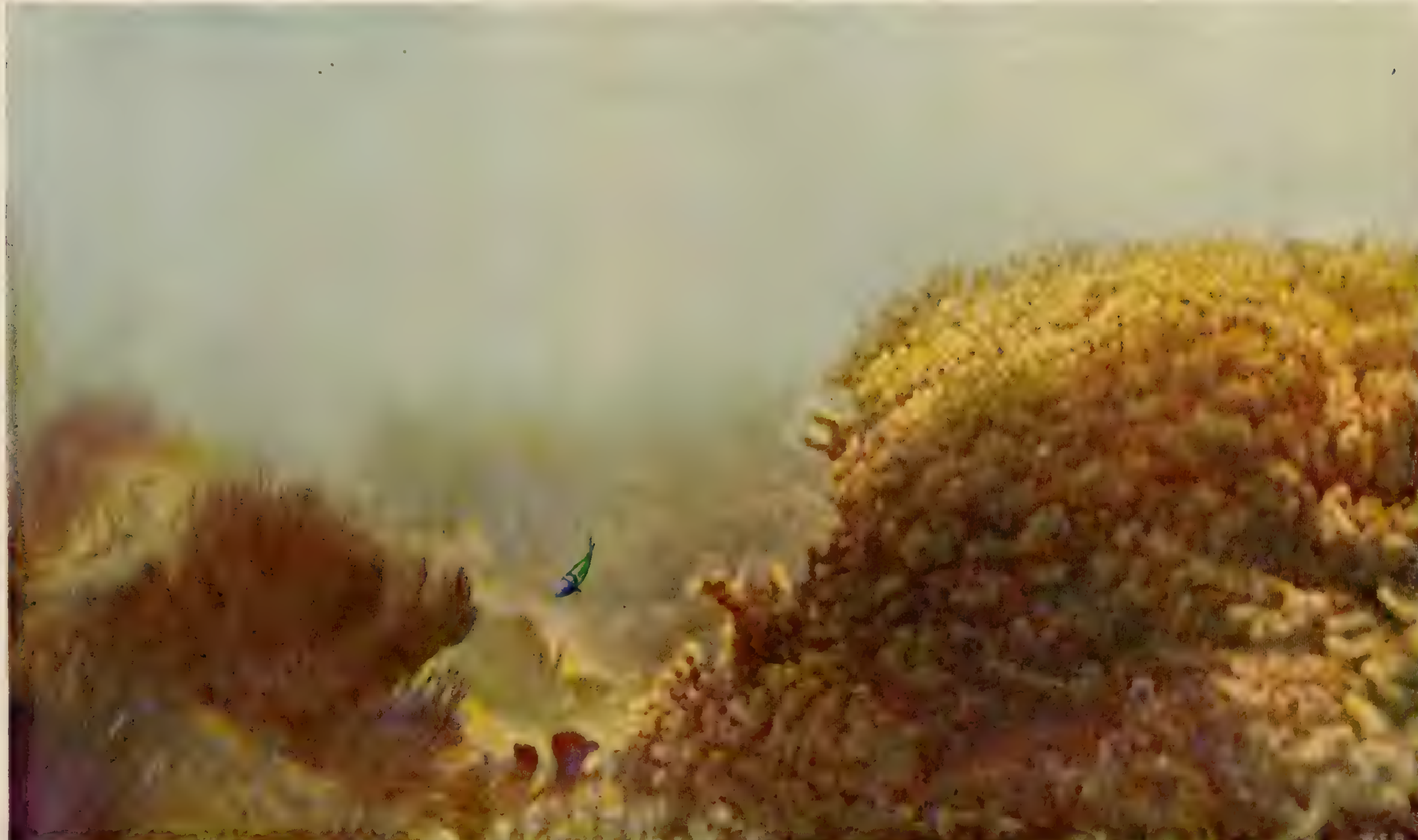
By ROY WALDO MINER

CURATOR OF LOWER INVERTEBRATES

A BAHAMAN CORAL GARDEN

GUIDE LEAFLET SERIES, No. 80

THE AMERICAN MUSEUM OF NATURAL HISTORY
NEW YORK, 1933



AN UNDERWATER PARADISE IN AN ANDROS CHANNEL

A bluehead swims out into a sunlit submarine valley, its gay uniform of blue, green, black, and white, in vivid contrast to the soft colors of a bank of *Porites* finger corals, tinted with yellow, pink, and violet

Diving in Coral Gardens

By ROY WALDO MINER

Curator of Lower Invertebrates

Reprinted from Natural History Magazine for September-October, 1933

GUIDE LEAFLET SERIES, No. 80

The American Museum of Natural History

New York, 1933

A SUBMARINE VISTA ON THE ANDROS REEF

Sunlit aisles of the sea forest floor with reef fishes swimming among the fronds of the tree-like gorgonians

Steadying myself by grasping a ladder-rung, I looked about me. A short distance away rose the coral reef, tier on tier, to the surface. Clusters of mushroom-like coral growths capped with gray-green and pink *Orbicella* formed the bulk of the reef. Purple and yellow sea-fans swayed back and forth with the motion of the water, while sea-bushes of soft and varied hue rose from slender stocks, their waving branches, extending upward in widely expanding parallel ranks, starred with hosts of feathery polyps. Caverns and arches of eroded coral, fantastic in form, showed clearly through the unbelievably transparent water or melted into the pearly blue liquid mist in the distance.

I took a few steps forward leaning against the push of the current, and glanced up to see the keel and underside of the launch bulking above my head with propeller and rudder looking very formidable from below. My air-hose floated coiling to the surface, while clouds of silvery bubbles, released momentarily from my shoulders, rose in expanding clouds. A disturbance of the water at the summit of the ladder attracted my attention. A pair of legs appeared weirdly on the rungs. The body was not visible, being concealed by the liquid mirror of the water surface. This was impenetrable to the view, but reflected an inverted image of the legs, giving the odd effect of a St. Andrew's cross! In a few minutes the rest of the figure and a helmeted head succeeded the legs, descended the ladder, and stood on the sea floor beside me. Looking through the window of the helmet, I perceived the smiling features of Roswell Miller, who, with Mrs. Miller and my artist, Chris Olsen, completed the personnel of my expedition for the American Museum of Natural History.

I motioned toward the reef and we advanced slowly in the direction of an outlying brain-coral that towered above us on a fantastically carved pedestal, with a cloud of bright yellow fishes flitting around its summit like canary birds. Rounding this mass, we entered a crooked passageway which led toward one of the great overhanging arches of coral rock. As we peered within, a moving form became visible in the watery shadows, then another.

Presently, a huge parrot fish, brilliantly blue, varied with deep violet, swam slowly out of the cavern, followed by two others in stately procession. Back and forth they sailed, staring toward us, occasionally nibbling at a bit of loose coral, portions of which they crushed with their white, parrot-like beaks, releasing powdery fragments which rose in clouds as they masticated them for the filmy nourishment they afforded. We signaled to each other and edged back toward the boat. The window of a water-glass penetrated the surface beside the bottom of a floating dinghy. We motioned with our arms, and the undersea tripod splashed down through the water to settle bottom side up at our feet, its legs extending upward from the square metal top. The heavy camera-box now came gliding down, hooked on the end of a cord. We slowly and painfully erected the tripod, carefully adjusting it in a favorable position. One must move with deliberation at the bottom of the sea. Attempts at rapid motion were futile and exhausting, but if we moved slowly, the water supported us in half floating fashion and we progressed easily with the effect of a slow-motion film. A little push with the foot and we glided over an obstruction to a considerable distance and settled down slowly and gently. After the tripod was erected satisfactorily, we returned for the camera-box. I reached for it but miscalculated the distance, and my hand grasped empty water about two feet in advance of it. Distances under water are deceptive to the vision, because of the unaccustomed density. Groping forward, I felt the handle of the camera-box, and had no difficulty in lifting, with one extended hand, a weight that both hands could scarcely raise from the boat's deck, in the open air. We carried the box over to the tripod, placed it in position, and took turns pressing the lever that actuated the mechanism of the camera. Unfortunately, by this time the parrot fishes had disappeared, though swarms of blue-heads and schools of jacks swam into focus.

As the focus of the camera had to be set at a predetermined distance before sending it down, it was impossible to focus on a fish directly, and it was tantalizing to see beautiful queen triggers, blue angel fishes, and grotesque trumpet fishes come into plain view at a distance of twenty-five feet, when we had carefully arranged our focus at ten feet.

After fifty feet of motion picture film had been taken, we carried the box back to the cord which hung suspended from the launch and sent it up for Captain Bethell to rewind and return to us again. When the film had completely run out, it was sent up for Mrs. Miller to change, and a second undersea box containing color film was sent down. This was Roswell Miller's specialty, and through its means he obtained beautiful motion pictures depicting the soft colors of the living corals and gorgonians and the brilliant hues of the fishes which lived among them. After a time, Chris Olsen took his turn with the helmet, and we worked our way carefully through the tortuous aisles of this undersea fairyland to observe more intimately the multitudinous variety of the creatures composing the closely interlocked association of forms characteristic of the living coral reef.

Our attention was attracted by a

COLLECTING "HONEY-COMB" ROCK ON SPRUCE CAY

Many of the smaller cays of the Bahamas are composed of eroded limestone rock honey-combed with cavities and winding passages of fantastic form, resembling a petrified sponge

SCOUTING FOR A FAVORABLE LOCATION TO DIVE

Members of the expedition using water-glasses to examine the sea-bottom for an advantageous position from which to study and photograph the coral reefs from the sea-floor

THE "STANDARD J." THE FLOATING HEADQUARTERS OF THE EXPEDITION

This forty-eight-foot gasoline launch, commanded by Captain Joe Bethell of Nassau, is well adapted for coral reef work. She has been used by Doctor Miner on two expeditions to obtain the material and observations for the American Museum's Coral Reef Group

ROSWELL MILLER AND HIS UNDERSEA COLOR CAMERA

The brass water-tight box contains a motion-picture camera adapted for Kodacolor. Mr. Miller succeeded in obtaining submarine color films of great beauty

MRS. ROSWELL MILLER DESCENDS BENEATH THE SURFACE

The heavily weighted helmet is being lowered over her head as she prepares to submerge

ridges exquisitely wrought with radiating star-shaped calices. Hues of delicate rosy pink shaded into cream-yellow tints, suffused at intervals with areas of orange and purple. We had brought with us specimens of this coral which had been colored artificially by our artists for use in the Coral Reef Group being constructed in the American Museum. We now took these with us down under the sea, and placed them beside the living specimens for comparison so as to test the accuracy of our colors. The result was very gratifying. At arm's length, they looked exactly like the real coral and blended with their living

wonderful cluster of golden yellow *Porites* coral which rose in an enormous dome above our heads. It was composed of a succession of expanded mushroom-like caps, completely covered with small conical mounds which gleamed in the sunlight flickering through the ripples overhead. Like most such growths, the caps were supported by eroded columns of dead coral limestone overgrown with encrusting sponges of scarlet, or green and yellow. Clusters of *Agaricia* coral grew vertically from the sides of the columns sculptured on both sides of their thin leaf-like expansions with close-set series of fine parallel

DOCTOR MINER ABOUT TO DIVE

He stands on a rope ladder while the helmet is being adjusted. The rungs of the ladder are a foot apart, enabling him to measure his depth as he descends

MANNING THE PUMPS ABOARD THE "STANDARD J."
Moxie, in the center, acts as tender. It is his duty to watch the divers and to pay out and take in the air-hose as needed

neighbors so perfectly that they could not be told apart!

As we stood looking at the coral, we suddenly became aware of a beautiful sight. From the open ends of a cluster of little whitish tubes, soft tufts, for all the world like penciled color brushes, came into view, slowly unfolding until flower-like heads of violet and purple spread themselves wide open from every tiny aperture. Even while this transformation was taking place, another cluster began to expand, and then another, until the dead and eroded rocky shafts of coral became alive with the bursting bloom of animal flowers. For these were the heads of beautiful sabellid sea-worms which are crowned with circlets of delicate petal-like breathing organs expanding to receive through their thin, translucent walls life-giving oxygen from the watery flood in which they are bathed.

One stands amazed at the wealth of detail which gradually dawns upon the vision as the attention is directed to the multitudinous forms of which the reef is composed. Here, a magnificent purple sea-bush spreads its comblike fronds before us. Every branch is covered with thousands of transparent cream-colored polyps each spreading eight raylike tentacles around a tiny dot of a mouth, so small that it can be seen only upon close examination. The sunlight shining through their translucent crowded bodies outlines every twig of their waving, treelike home with a multiple margin of glory.

A cluster of fluffy green clubs rises from a crevice between two rounded brain-corals. The starry blanket covering them seems to be very soft and deep. I touched it with a speculative finger. The soft clubs magically transformed themselves into a cluster of hard, finger-shaped projections of bright purple! Looking closely, I saw that the fingers were covered with thousands of pinholes, and, as I watched, one filmy form after another peered forth and gradually elongated until the purple surface of the fingers became clothed once more with fluffy green.

TWENTY-FIVE FEET BELOW THE SEA SURFACE
The motion-picture camera is enclosed in a water-tight box and is actuated by a lever from the outside

The sea-clubs, sea-bushes, sea-whips, sea-feathers, and sea-fans are all grouped together by scientists under the name, *Gorgonia*. Unlike the corals, their tree-like skeletal support is flexible, being composed of a tough, horny substance invested with a crust of felted calcareous needles, irregularly shaped and of extremely small size. A labyrinth of canals penetrates this crust, opening frequently to the outside by means of circular or oval apertures about the size of a pinhole. The living substance of the polyps is tubular and invests the canals throughout, projecting through the pinholes, when expanded, as tiny tube-shaped creatures crowned by a circlet of eight threadlike tentacles surrounding the central mouth-opening. If touched, they contract and withdraw into their hollow retreats.

The reef-forming corals resemble the gorgonian polyps in appearance and structure except that their cylindrical polyps are surmounted by many tentacles in multiples of six, and have the power of laying down a skeletal structure of carbonate of lime beneath and around their soft bodies. The concerted action of millions of coral polyps builds up the immense and complicated limestone structures which form the coral reef. The coral skeletons may form crusts over the sea bottom, or may rise in dome-shaped masses like the brain and star corals (*Mæandra* and *Siderastræa*), or postlike growths capped like mushrooms, as in the case of the orb corals (*Orbicella*). They may be leaf-shaped, as in *Agaricia*, or like rosettes, or sinuously petalled flower-like colonies, characteristic of *Isophyllia* and *Mussa*. Among the most beautiful and striking corals of the Bahaman reefs are three species of *Acropora*, which forms branching structures, the most delicate and fragile of which is the fan coral

DOCTOR MINER FOUR FATHOMS BELOW THE SURFACE
His sixty-five-pound helmet rests lightly on his shoulders, because of the supporting power of the sea water

(*Acropora prolifera*). The staghorn coral (*Acropora cervicornis*) builds loosely branching many-tined skeletons reminding one of the antlers of a stag, from which its name is derived. The largest and most massive of the three is the great elkhorn, or palmate coral (*Acropora palmata*) which forms gigantic growths with branches like beams, expanding into broad, palmate tips, reminding one of the antlers of an elk. This species dominates the great Andros barrier reef, where the scene of the American Museum's Coral Reef Group is laid. All the other species of coral are found there, but are overshadowed by the great orchard-like groves of the elkhorn, which rise in tangled thickets of marble trees tinted with saffron.

COMING TO THE SURFACE AFTER A DIVE
Moxie reaches down to remove the helmet as the head of the diver appears above the water

Of the five expeditions I have led to obtain the material and observations for the Coral Reef Group, the first three centered around the Andros reef. The two latest, including that of the present year, concentrated on the beautiful reefs of Rose Island. Here, again, all the species characteristic of Andros are present, but the elkhorn coral is relatively rare, while the dome-shaped corals and the gorgonians are particularly abundant. The Rose Island reefs thus form a strongly contrasting association as compared with the Andros Barrier Reef. The latter is massive, wild, and grotesquely beautiful in its effect, as the coral growths run riot in protean variety and menacing grandeur.

The Rose Island reefs, on the other hand, are filled with soft and colorful beauties, due to the rising terraces of rounded species, cap beyond cap, dome beyond dome, their foundations columned and buttressed, pierced by caverns, arches, and winding passages. Their ethereal beauty is heightened by the multitude of waving gorgonians; sea-plumes, sea-feathers, and sea-bushes of many soft and varied hues—purple, violet, brown, tan, yellow, and lavender—waving back and forth in the sunlight which descends through the heavenly blue waters in beams of light. When the water surface is roughened, these sunbeams may be seen flickering and dancing

A PURPLE SEA-FAN WITH FULLY EXPANDED POLYPS

Waves back and forth in the sunlight glinting through the lacy openings of the delicate meshwork composing its flexible fan-shaped "skeleton"

up and down, piercing the water in shining spear-shafts, advancing and retreating like Northern Lights. Out from behind the clustered domes dart fishes of every brilliant hue, in almost every unbelievable contrast of pattern and color, while from coral arch and deep, dark cavern, the bulky, bright-colored parrot fishes, the huge, somber jew-fish, and the variegated and changeable Nassau grouper, peer and nose and glide in slow and stately parade. Now and then a great school of silver-blue jacks with clean-cut bodies and small-peduncled, slender-finned tails will glide across the view and even surround us completely. Hundreds of them! All glide by, swimming in the same direction, passing out of sight, their silvery-blue bodies suddenly vanishing in the silvery-blue haze of the undersea. Suddenly they appear again out of nowhere and sail past in the opposite direction. This will happen several times, as if the entire school were formed into a committee of the whole to inquire into the doings of their strange, helmeted visitors from the upper world.

It is true that there are fish-serpents in this coral paradise of the fish world. Long and slinky green or spotted morays with small serpent-like heads and sharp needle-like teeth lurk among deep crevices of coral. But they are seldom seen, and if we are careful not to thrust hand or foot into an unexplored hiding place, there is little danger. Once, a barracuda, more to be dreaded than sharks, swam over my head while I was engaged with a camera; but I didn't know it till I came to the surface, when Captain Joe told me about it. However, it did not disturb me and went about its business elsewhere. As for sharks, one is occasionally seen about the reef, but both sharks and barracudas are open-water fishes. They seem to need

GOLDEN YELLOW *PORITES* CORALS

Like nuggets of gold, they are massed together in immense clusters, capping irregular columns of eroded limestone

A CORAL FOREST ON THE ANDROS REEF

Stone trees, fifteen feet in height, with closely interlacing branches, present weird undersea prospects, in striking contrast to the dome-shaped coral growths characteristic of the Rose Island reef

sea-room, and do not usually bother with the serrated entanglements of coral reefs. So, if one is careful about crevices, and watches not to step on a sting-ray, and keeps one's ankles away from the needle-like spines of "sea-eggs," as the natives ironically call the big black sea-urchin (*Centrechinus antillarum*), there is not much to fear, not nearly so much as there is in crossing Broadway during the rush hour.

Day after day, whenever the weather permitted, the good launch "Standard J." took us from clump to clump of the reefs at Rose Island, Athol Island, and Long Shoal. We had three undersea cameras, two for black and white motion pictures, and one for color film. The latter and one of the former were the ingenious contrivances of Roswell Miller. There were also two helmets and pumps, which thus enabled two persons to get under the sea at a time. We could walk about together and converse simply, by means of predetermined signs which enabled us to compare notes for our work. At times Chris Olsen would go down with palette and easel constructed of non-corrosive metal. He would set up his easel on a convenient clump and fasten into it an oiled canvas securely mounted on a sheet of plate glass. Then he would actually make sketches with oil colors directly from nature, undersea, at a depth of fifteen or twenty feet. At first, he used the regulation artists' brushes with wooden handles, but whenever, inadvertently, he let go his hold on one, it would float to the surface and Moxie would have to row out with a dinghy to get it. Besides, in the wash of the tide, a brush is not steady enough for applying color. So Olsen finally used a palette knife instead, which was much easier to manage.

I succeeded in getting motion pictures

MANY-BRANCHED GORGONIAN SEA-BUSHES

Their vertical fingers, extending upward in closely parallel ranks, are covered with feathery white polyps, which outline the slender subdivisions like a halo of light as the sun shines through them

DETAIL OF A CORAL CLUSTER ON A ROSE ISLAND REEF

Huge dome-shaped masses of tawny or gray-green *Orbicella* corals, suffused with delicate pink, rise in towering clusters to the water surface, interspersed with patches of fluffy red and green algæ and branching gorgonia

NUMEROUS SPECIES OF GORGONIANS GROW AMONG THE CORALS

These are flexible coral trees each built up by thousands of tiny polyps, constructed by them of a horny substance, in contrast to the limestone "skeleton" built by stony coral polyps

CHRIS OLSEN PAINTING AT THE BOTTOM OF THE SEA

Equipped with diving helmet, monel metal palette and easel, the expeditionary artist made sketches of coral reefs twenty-five feet below the surface. He used oil-colors on an oiled canvas stretched over a sheet of glass

A GREAT ELK-HORN CORAL

High on the summit of the reef, close under the water surface. The spreading tips resemble the antlers of an elk

of him at work, by going down in another helmet for the purpose and mounting an undersea camera on the tripod at a carefully measured distance. An enlargement from a portion of one of these films is shown in this article.

Of course, it was possible to make only the preliminary sketches undersea. The finished studies were made at our headquarters in Nassau, where our studio was established at the hospitable home of Mr. Edward S. Toothe.

Mr. and Mrs. Roswell Miller were splendid coworkers on this trip. They are excellent swimmers and occasionally, while both helmets were in use, I would sense a splash above my head and look up to see a graceful, red-clad figure break through the mirrored water-film, and Mrs. Miller would come diving down in a stream of silvery bubbles, or we could see her partly penetrating the surface as she swam about the boat for long periods, looking down at Mr. Miller and myself as we worked, peering through a water-glass held in front of her.

At other times we had the pleasure of introducing His Excellency Sir Bede Clifford, the Governor of the Bahamas, and Lady Clifford to the undersea world. They came down in turn, and explored the face of the reef, working their way through the crevices between the coral clumps, facing the inevitable camera at a depth of twenty feet. The Bahaman officials were all greatly interested in our work, both in this and in all the previous expeditions, and did everything in their power to assist us.

Occasionally, when the weather was too rough for diving, we went ashore on one of the rocky cays which abound in the waters near Nassau, and, by means of hammer and hatchet, hacked off huge fragments of the eroded "honeycomb

CORAL GROWTHS LIKE GIANT PETRIFIED MUSHROOMS

Rise above waving fronds of sea-fans and sea-bushes, melting into the luminous blue of the distant watery prospect

A SCHOOL OF SILVERY JACKS

They swam solemnly past the undersea workers, as if to examine the intruders into their submarine Paradise

rock" of which they are composed. This rock is wrought by wave and weather into most fantastic forms; in fact, the whole surface of the cays is full of holes and passages contorted and twisted and anastomosing like a petrified sponge. We obtained more than a ton of this rock and shipped it to the Museum, where we are now reproducing a portion of such a rocky cay as a part of the foreground in the upper section of the group, using the original material in the process.

This group is now nearly finished. A few months more and the exhibit will be complete, after ten years of arduous work. During that time, five expeditions have been undertaken to the Bahamas, the first, in December, 1923, for preliminary observations and arrangements; the second, in 1924, secured forty tons of coral, many feet of undersea photographs and motion pictures of the Andros reef, and many water-color studies from life, using the Williamson undersea tube and diving helmets for the purpose; the third, in 1926, obtained the casts and sketches of the fishes for the group, as well as sketches for the great cyclorama representing the scene of the coral lagoon above the water; the fourth, in 1930, procured the gorgonians needed, properly prepared, and additional undersea motion pictures and observations, utilizing diving helmets; the fifth, during the spring of the present year, also utilizing diving helmets, a check-up expedition, made final observations and additional motion pictures from the sea-bottom, and obtained rock for the coral island.

These five expeditions have been interpolated between long periods of work at the Museum, preparing and coloring corals, erecting the elaborate framework to support them in the group, consisting of more than seven tons of structural steel,

SIR BEDE CLIFFORD, GOVERNOR OF THE BAHAMAS

Inspecting the Rose Island gardens on the sea bottom. Governor and Lady Clifford were enthusiastic divers

modeling and coloring fishes and the other multitudinous forms of undersea life composing the coral reef association. The great upper and lower backgrounds had to be colored for this huge two-storied group which exhibits the above-water and under-water scene simultaneously. Eleven-foot plate-glass backgrounds had to be inserted and colored, and the under-water illusion had to be worked out. Various items remain to be completed. When finished, it is estimated that the exhibit will be the equivalent of thirty ordinary Museum groups in size and difficulty of preparation. It will occupy one-third of the entire farther end of the great Hall of Ocean Life, probably the largest museum exhibition hall in the world.

LANDING THE "HONEY-COMB" ROCK AT NASSAU

The expedition brought back more than a ton of this rock to build a rocky cay as a part of the Coral Reef Group in the American Museum

THE WORLD OF FISHES

Guide to the Fish Collections of The American Museum of Natural History

By WILLIAM KING GREGORY

and FRANCESCA LA MONTE

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THE AMERICAN MUSEUM OF NATURAL HISTORY

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Fig. 2. Remora, the Shipholder. (After Camerarius, 1654).

INTRODUCTION

"FISH stories" have been cheerfully told by romancers of all ages, and a public that loves to be humbugged has greedily believed them.

The mermaid, the sea-serpent, and the giant "devil fish" that threw its slimy tentacles around a Chinese junk are among the more famous narratives of marine life, but there are others equally ancient and astonishing.

The myth of the Shipholder, for instance, lasted from Aristotle's time to the end of the Middle Ages. This slender, smallish fish with an adhesive disc on top of its flattened head, according to Pliny "bridles the impetuous violence of the deep" and stops large vessels in their course merely by fastening itself to them. To this fish, the Remora, prominent roles in ancient naval encounters have been assigned by credulous authors who should have known better.

In the same delightful manner, a learned gentleman named Conrad Wolffhart rose in the sixteenth century to announce a "downpouring from heaven" of little fishes, illustrating his story with a woodcut of the fishes dropping as a gentle rain from heaven upon a village in Saxony.

Man's small imaginative efforts have, however, been put to shame by nature's own inventions. No sixteenth century collection of zoological yarns could rival the contents of nature's unique collection. For here are fishes with bifocal spectacles, or four eyes—two for looking above water and two for seeing below the water line; fishes fully equipped with

rod, line, hooks and dangling bait; fishes that can shoot—water—with deadly aim; fishes carrying electric batteries on their backs or tails; fishes that drown if prevented from rising to the surface for atmospheric air; fishes that hop about on land. "Believe it or not," there is a species of black, deep-sea Anglers in which the female is sometimes a thousand times heavier than the male, who dangles like a pendant from the cheek of his huge mate.

Our object, however, is not to lay undue emphasis on the numerous freaks and oddities of nature's Cabinet of Curiosities, but to exhibit fish life in its more truly representative phases. The Hall of Fishes of the World contains representatives of only a very small fraction of the twenty thousand already known species of fishes. It aims, however, to present a selection of the better known families, classified and arranged according to their natural blood relationships with each other.

Under Biology of Fishes, we consider the fish as a natural mechanism. Here our object is to look below the surface and see the wheels go round,—to see how the fish lives, moves, eats, etc.

The collection of Game Fishes appeals not only to the student, but to everyone who loves fishing as a sport. It contains several of the biggest fish ever caught on rod and reel, according to available records. The Sailfish Group and the gigantic Marlins caught by Dr. Zane Grey form the chief features of this exhibit.

In general, the arrangement of this guide follows that of the Hall.

SECTION I

ARCHAIC FISHES

(Sharks, Rays, Lampreys, Lungfishes)

[Cases, 7, 11, 5, 3, 1; groups; inner room]

SHARKS

The Sharks of the present are the survivors and descendants of sharks that lived many millions of years ago in the Devonian age of the earth's history. [*See* Fossil Fishes]. They differ from ordinary fishes especially in the gristly or cartilaginous state of the skeleton, which is not strengthened by bony tissue, but by deposits of calcium carbonate and calcium phosphate. The skeleton as a whole is in a primitive or generalized state as compared with that of higher vertebrates and the same is true of the brain, blood vessels, digestive system, etc. Hence a study of the anatomy of the shark forms an excellent introduction to the anatomy of higher vertebrates, including man.

The diagram in Case 11 attempts to visualize the evolution of the body forms of the higher sharks from some ancient central stock which is most nearly typified by the existing Sand Shark (fig. 1 of diagram). Each figure stands for a family or group of related forms, and the branching of the lines indicates the relationships.

The whole surface of the shark's body is covered, not by scales, but by denticles or little teeth, or plates, called "shagreen." Because of its roughness and durability, the skin of the shark has been considerably used in place of sandpaper for polishing wood and ivory, as well as for ornamental purposes. The commercial leather known as "galuchat" is shark skin. Around the mouth of the shark, these denticles become enlarged and give rise to the teeth.

The swifter sharks, like the Mackerel Shark (Case 11), pursue and devour live fish, but the more sluggish ones, like the Nurse Shark are content with offal. Some with blunt teeth, like the Port Jackson Shark (Case 7), crush shellfish, while some with very large mouths and reduced teeth, such as the Whale Shark (*see* separate case) and the Basking Shark, (above Case 11), feed like whales on small copepods and other floating, shrimp-like forms.

Reproduction: Sharks produce but a few eggs at a time, in contrast to the hundreds of thousands produced by a single Codfish; hence they can afford, so to speak, to invest a large amount of capital in each egg, that is, to endow the young with a very large yolk. This nourishes the young for a long time, so that they are well equipped to take care of themselves when they are hatched. In some sharks, however, the eggs

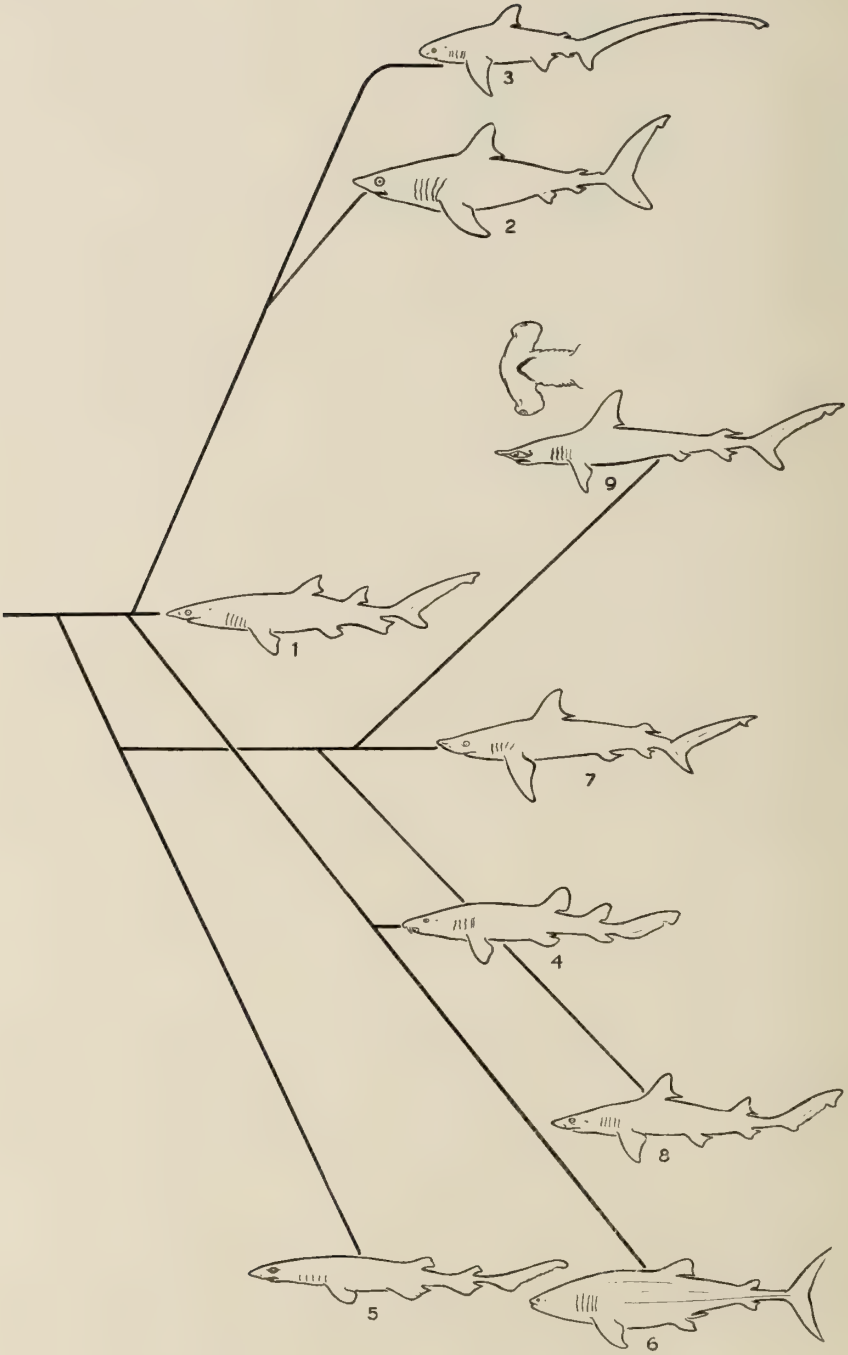

Fig. 3. Evolution of the Body Form of Sharks.

develop within the oviducts or egg ducts, and the young draw nourishment from the mother by means of root-like outgrowths from the region of their gills.

The Port Jackson Sharks (Heterodontidæ). [Case 7]: During and before that ancient period of the earth's history in which the vast swamps and forests of Pennsylvania were accumulating their stores of coal-forming vegetation, the shallow seas of the world swarmed with ancient sharks, many of which bore curved spikes on the front margins of their fins. The more specialized forms of these early sharks became extinct, but one family survives,—the Port Jackson Sharks—which are still found living in the Pacific Ocean. These retain the stout fin spines and whorl-like crushing teeth of their vastly distant ancestors. They lay eggs which are enclosed in a spirally twisted egg case.

The Spined Dogfishes or Squaloid Sharks (Squalidæ). [Case 7]: These sharks are far removed from the higher sharks and appear to be related to the ancestral stock of the Rays. They have lost the anal fin; the teeth are usually closely packed and more or less uniform. Some of the deep-sea members of the family are only a few inches long, while the Greenland Shark is said to reach a length of twenty-four feet. In the common Spiny Dogfish, the eggs are surrounded by a horny shell, but they are not laid; the egg shells break down within the egg duct in which the young are retained until fully developed.

The Notidanoid Group. [Case 11]: This group includes the long-bodied, deep sea Frilled Shark (*Chlamydoselache*), the Cow Sharks, and their allies. The Frilled Shark has trident-shaped teeth, but in the Cow Sharks and their allies the lower teeth are saw-like. Very large yolked eggs are laid. There are not less than six large gill clefts, and but one dorsal fin.

The True Dogfishes or Cat Sharks. [Case 7]: These sharks are variously called Scylliidæ, Scilliorhinidæ, and Catulidæ. As in all the higher sharks, there are two dorsal fins without spines. These are displaced backward, and the lower lobe of the caudal fin is not much produced. Their teeth are many-pointed. The egg cases are elongate and quadrangular with the corners produced into long, curling filaments. This family dates from the Jurassic period. The common "Dogfish" (*Mustelus*) does not belong to this family but is related to the Requiem Shark group. (*See* below).

The Sand Sharks (Odontaspidæ, Carchariidæ). [Case 11]: These are perhaps the most central or generalized of the higher sharks. The body is perfectly normal or shark-like, with none of the fins reduced or displaced. The teeth have needle-sharp points with small accessory cusps on either side of the yoke-like base. The gill slits are of ample

size and lie entirely in front of the pectoral fin. The checker-like centra of the backbone are of the asterospondyl or star type, with four uncalcified streaks radiating outward from the center. The family of the Sand Sharks dates from the Cretaceous. A deep sea member of it, *Scapanorhynchus*, has an elongate, depressed snout.

The Nurse Sharks (Orectolobidæ). [Case 11]: The Nurse Sharks are related to the Sand Sharks but are specialized for a more sluggish life. The head is typically broad and more or less depressed; the teeth closely packed, flattened, or not needle-like; the dorsal fins more or less displaced backward. There are one or more flaps or projections of skin around the mouth. The eggs of the Nurse Shark are about as large as goose eggs, with a delicate, horny shell. It is believed that these eggs are retained in the body during the entire incubation period and free young released as in the Requiem or Carcharinid sharks. In this respect the Nurse Sharks are intermediate between the true Dogfishes (Scyllidæ) which are oviparous or egg-laying, and the Requiem Sharks which are viviparous (producing living young). Fossil representatives of the Nurse Shark family date from the Eocene.

The Mackerel Sharks (Isuridæ). [Case 11]: represent a swift-swimming adaptation from some ancient relative of the Sand Sharks. The contour of the body recalls that of the swift-swimming Bonitos [Case 32]. The upper lobe of the tail-fin is turned sharply upward; its lower lobe is produced downward so that the tail as a whole is more or less lunate. Its base is supported by lateral keels. The second dorsal and anal fins are much reduced. The teeth range from simple bodkin points in the Cretaceous *Orthacodus* [*see* Fossil Fishes] to the broad, serrate triangles of the Whale Shark and the far larger teeth of the gigantic extinct *Carcharodon* shown at the entrance of the Fossil Fish Exhibit. The gill slits are very large, wholly in front of the pectoral fins. The White Shark, or Man-Eater, is a gigantic member of this family. The whale-like Basking Shark [above Case 11] is another giant, with the gill rakers prolonged into a sieve for straining from the water multitudes of minute floating crustaceans.

The Thresher Sharks (Alopiidæ). [Case 11, also above elevator]: These are heavy-bodied derivatives of the Mackerel Shark group, in which the enormous tail is used for rounding up the schools of fish upon which the Thresher feeds.

The Requiem Sharks (Carcharinidæ). [Case 7]: The most numerous and dominant group of the present day, these sharks arose later than most of the other families, their fossil teeth dating back at most to the Eocene epoch. They have advanced beyond the lower sharks (such as the true Dogfishes) by retaining the eggs within the egg-tube until the

young are well developed; the young are, therefore, born alive. The Requiem Sharks may be distinguished from the Sand Sharks (*Carcharias*) by the fact that the last one or two of the rather small gill slits lie above the base of the pectoral fin. The base of the tail is notched above and below; the upper lobe of the tail is turned partly upward and the lower lobe is more or less produced. The body form is long and slender in the Blue Shark (*Prionace glauca*). A group at the southwest end of the hall shows a Blue Shark surrounded by its new-born young, swimming about under Sargasso weed and among the wreckage which drifts into the comparatively currentless ocean area known as the Sargasso Sea.

In the New York Ground Shark (*Carcharinus milbertii*) [Case 7], the body is stout, with a massive snout.

The Smooth Dogfish (*Galeorhinus* or *Mustelus*) somewhat resembles the true Dogfishes (Scylliidæ), but differs from them in the more normal position of the first dorsal fin which is not displaced backward. The teeth also are flattened and the fish feeds on crabs, squid and many other creatures. The type represents a bottom-living adaptation of the free-swimming Carcharinid stock.

The strange Hammerhead Sharks (*Sphyrna zygæna*) appear to have derived from some more normal member of the Requiem Shark or Carcharinid group, in which the snout was broad and shovel-like. The Bonnet Shark (*Sphyrna tiburo*) shows an intermediate stage in the widening of the head. The Hammerhead is a swift swimmer and makes sharp turns with great agility, apparently using the flattened head as a "bow rudder."

The Japanese Sawfishes (Pristiophoridæ) [Case 7], like the true Sawfishes (*Pristis pectinatus*) [above Case 7], have their nose produced into a very long, flat rostrum, armed on each side with a row of teeth. But a comparative study of the skeleton and internal anatomy of these forms shows that the Japanese Sawfish is more nearly related to the spiny-finned sharks, while the true Sawfish is closely related to the Guitar Fishes [Case 5]. In other words, the saw-like rostrum has been acquired independently in two distantly related groups.

The Whale Shark (*Rhineodon typus*): In a case near the entrance to the Hall of Ocean Life stands a scale model of the Whale Shark, the largest living fish. This fish has been measured up to 45 feet in length, and is estimated to reach 70 feet. It resembles a whale in manner of feeding as well as in size. Its teeth, about $\frac{3}{16}$ of an inch in height and 5000 in number in each jaw, are set in many card-like rows, but are useless for biting. Its food consists of small organisms filtered out of the water by its sieve-like gill rakers. Despite its huge size, this fish is harmless. It occurs in warm waters of the ocean.

The specimen of which this is a model (1/6 scale) was 32 feet long. It was captured near Long Key, Florida, June 9, 1923.

Recent investigations indicate that the Whale Shark represents a peculiar family which is a specialized derivative of the Mackerel Shark group.

SKATES AND RAYS

"Winged Sharks"

[Case 5 and Inner Room]

The strange looking Skates and Rays of the present time may be regarded as transformed Sharks, in which the body became greatly

Fig. 4. Russell J. Coles harpooning a Devilfish.

flattened and the pectoral fins enlarged and widened into "wings" which finally became the principal organs of locomotion. The tail is reduced to a long, trailing rudder. The gill slits have been displaced onto the lower side and the water for the gills is pumped in and out through the large spiracles behind the eyes.

Several still existing forms show some of the stages by which this transformation has been brought about. The Monkfish (*Rhina squatina*) is, in fact, more or less intermediate between the Spiny Dogfishes and the Rays. Its pectoral fins are enlarged, but are still separated from the head by the gill slits, which remain lateral in position. The skull and jaws also are of the primitive shark-like type. In the Guitarfishes

(*Rhinobatus*) the front part of the enlarged pectoral fins is fastened to the side of the head and the gill slits are on the lower surface.

The true Sawfishes (Pristidæ) are essentially *Rhinobatus*-like forms in which the greatly prolonged snout has acquired a row of "teeth" on either side. These, like the teeth in the mouth of sharks, have been evolved out of the tooth-like denticles on the surface of the skin.

In the Electric Rays or Torpedoes [case 5 and Inner Room], part of the enlarged muscles of the breast fins have been transformed into electric batteries which consist of layers of alternating tissues of different electric potential, like the plates of a voltaic pile. These fishes are capable of giving a powerful electric shock.

In certain Eagle Rays [Case 5 and Inner Room], the front ends of the breast fins begin to project beyond the mouth, and in the Manta or Devil Fish these forward projections give rise to movable flaps or "horns" which appear to assist the fish in scooping into the broad mouth the small floating creatures upon which it feeds. The large central fish of the Inner Room is the model of a Manta taken off the west coast of Florida in 1915. It measures 17 feet across the outstretched wings. Also in this room, against the wall, is a Sting Ray, its whip tail bearing at the base a strong saw-edged spine which can inflict a severe and irritating, but not specifically poisonous, wound.

The Skates lay eggs enclosed in tough, horny coverings, the four corners of which are prolonged into filaments. These egg cases are frequently washed up on northern beaches. In the Sting Rays and Eagle Rays the young are developed in the egg duct and the embryos draw their nourishment from the mother by means of filaments that extend from their gill openings.

CHIMAEROIDS

Silver Sharks

[Case 3]

The existing Chimaeroids, or Silver Sharks, nearly all deep-sea forms, are the descendants of certain specialized sharks of the Jurassic period. [*See* Fossil Exhibit, case 6]. The living *Rhinochimæra*, for instance, with its long rostrum and tapering tail, strongly recalls this ancient stock, while *Harriotta*, a black fish from the great depths of the Atlantic and Pacific, is a caricature of *Rhinochimæra*.

The Chimæroids progress chiefly by means of their wing-like pectoral fins. Their teeth and powerful jaws are adapted for biting and crushing. In external appearance, as well as in their cartilaginous skeleton and general anatomy, they are clearly allied with the sharks although in

certain other features they parallel the higher fishes. Their mode of development is shark-like. Their eggs are enclosed in tough, horny egg cases which probably lie on the sea bottom. When the young are ready to escape, the egg case opens along hinge-like folds.[1]

CYCLOSTOMATA

Lampreys and Hags

[Case 3 and group]

This class includes the two groups of fishes known as the Hags and the Lampreys, eel-like forms with jawless, sucking mouths. With these mouths they fasten themselves on larger fishes and feed upon them until nothing is left of their prey but an empty skin.

The Hagfishes are the vampires of the ocean, a career for which their sucking mouth and their tongues armed with rasping teeth well fit them. The body of the Hagfish is heavily covered with mucous which it also exudes in quantity as a defense when caught, giving it the popular name of "Slime Eel."

These fishes appear to be the highly modified and degraded descendants of the Ostracoderms, the oldest known forerunners of the backboned animals; the intervening stages are missing from the record.

The Sea Lamprey and its Nest: The group to the left of the Cyclostome case was brought as a unit from a stream near Smithtown, Long Island. These fishes, by means of their suctorial mouths, root up and push about the pebbles of clear, shallow streams in order to make a nest in which to spawn.

DIPNOANS

Lungfishes

[Case 1]

All fish breathe oxygen, which is dissolved in the water that passes over their gills, but a few fishes also have true lungs, by means of which they can breathe even when the water in which they live gets foul or dries up. These are the famous Lungfishes of Australia, Africa, and South America.

These interesting relics of long past ages also have four limbs, in the shape of paddles, which are equivalent to the fore and hind limbs of land-living animals.

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[1]These fishes and their development have been described in detail by Bashford Dean, in his "Chimæroid Fishes and their Development." Publications of the Carnegie Institution of Washington, 1906, number 32. 195 pages, plate, 144 figures.

The Lungfishes are distantly related to the ancestors of the swamp and land-living amphibians.

The Australian Lungfish (*Neoceratodus*) is found today only in the Burnett and Mary Rivers in Queensland, Australia, but many millions

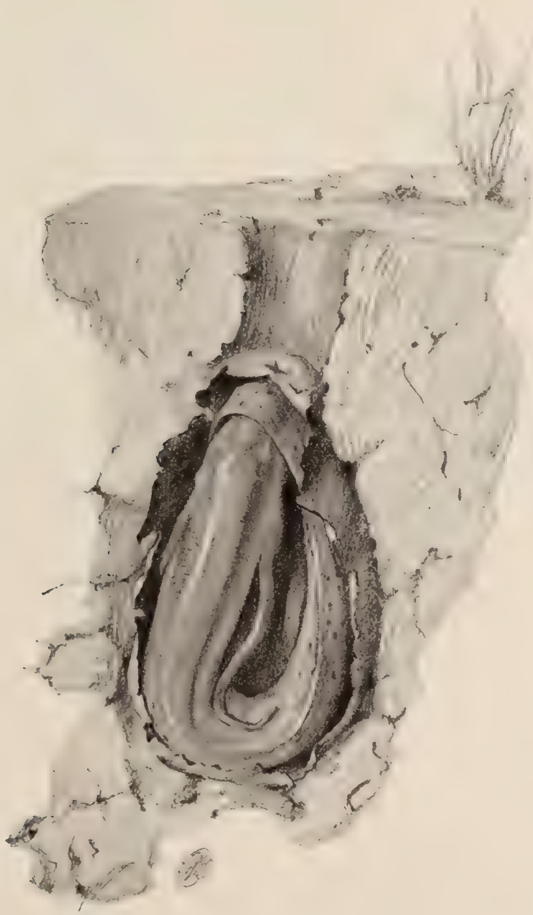

Fig. 5. A Lungfish in its Burrow. Drawn by D. Blakely.

of years ago its ancestors left their peculiar fan-like dental plates and other traces in the swamps of the Devonian and subsequent ages in many parts of the world, from India to Pennsylvania and from Great Britain to Australia.

The modern fish lives in stagnant pools or waterholes. At irregular intervals, it rises to the surface and protrudes its snout in order to

empty its lung and take in fresh air. The development of this fish from the egg is shown on the wall chart nearby.

The African Lungfish (*Protopterus*) has the fore and hind limbs prolonged into tapering filaments, which may be useful in creeping over the bottom of the marshes in which it lives. When the dry summer season comes on and the marshes are drying up, the lungfish buries itself in the mud, excavating a burrow in which it lies coiled up. The glands of the skin secrete a thick mucous, which, when dry, covers the fish like a bag, only a little hole being left around the mouth, through which the fish breathes. For many months the fish lives on its own fat, in a torpid state. When the rainy season returns, the water dissolves the cocoon-like bag and the fish escapes, none the worse for its long fast. A model of the Lungfish in its mud ball may be seen in Case 53.

The South American Lungfish (*Lepidosiren*) is even more eel-like in appearance than its African relative. It also lives in swamps and buries itself in the mud in a tubular burrow during the dry season, escaping when the rainy season returns.

The eggs are deposited in underground burrows at the bottom of the swamp; the male fish standing guard over them. During this period its hind limbs become enlarged and covered with a rich growth of blood-red filaments. These are thought to serve as an accessory breathing organ which enables the male to guard the nest without being forced to leave it and go to the surface to breathe air.

SECTION II

THE BIOLOGY OF FISH

[Cases 53, 54]

Development of Fish from the Egg: [Case 53 and wall chart]: Fishes, like all other backboned animals, reproduce themselves from a *zygote* which results from the union of two germ cells, one from the female, the other from the male parent.

The female germ cell is called an *ovum*, or egg, (plural *ova*); the male germ cell is called a *spermatozoon* (plural *spermatozoa*), or sperm. The egg is commonly said to be "fertilized" by the male element because the male cell starts the process of development. But the male cell does much more than this since it brings with it all the hereditary tendencies derived through the father, while the egg carries the hereditary tendencies derived through the mother.

Spawning (*External Fertilization*): In the higher fishes, the union of the male and female germ cells usually takes place in the water, into which they are discharged by the parents at the time of mating. In this case, fertilization is said to be external. When the eggs are discharged into the water and fertilized, they either float near the surface (pelagic eggs) or sink to the bottom (demersal eggs).

The pelagic eggs are very small, often less than a millimeter in diameter. They are transparent and often contain a large globule of oil. Such eggs are produced in countless numbers by pelagic fishes of many families (cods, flounders, mackerels, some herrings, etc.).

The demersal eggs are larger, heavier and more opaque. Those of the salmon, for example, are about 5 millimeters ($^3/_{16}$ of an inch) in diameter. In many demersal eggs, the outer egg membrane is viscid and adhesive, so that the eggs readily stick to each other or to rocks, stones, or bits of seaweed.

When fertilization is external, the eggs extruded at one time are usually very numerous, sometimes amounting to many millions, in order to compensate for the wholesale destruction of the eggs and young by other creatures or by unfavorable conditions of the environment. The rate of development is dependent upon the size of the egg (large eggs with much yolk tend to develop slowly); the temperature (cold water slows down the development), and racial tendencies which tend to retard or accelerate development. In the small eggs of the anchovy, development from the time of fertilization to hatching takes only two or three days, while the larger yolked eggs of the salmon develop in colder water in 35 to 148 days. After perhaps several weeks, a tiny larval fish is ready to start life on its own account. It begins by taking in only very small

Fig. 6. Development of the Fish from the Egg. The Australian Lungfish. Chart drawn by W. Benckert.

organisms and then passes step by step to larger and larger kinds of food as its size and strength increase.

Differing widely from the modernized methods of development of the Teleosts or higher fishes [Case 53], is the old-fashioned type of development characteristic of the Ganoids, the Lungfishes and the amphibians. On the chart to the left of the Shark Group, are shown some of the successive stages in the development of the Australian Lungfish, *Neoceratodus forsteri*. Figure 1 shows the fertilized egg, greatly magnified, the egg itself being about one-eighth of an inch in diameter. The lower part of it is filled with yolk. In Figure 2, the egg has divided into halves. In the succeeding figures, this process of subdivision continues until many millions of cells result. The general outline of the embryo is beginning to be seen in Figure 7, the head being at the left. In Figure 10, we note the already swollen brain, with the eyeball. The heart, the muscle segments of the body, and the blocks of the spinal column are also indicated. The baby fish is shown in Figure 13, greatly magnified. Figure 14 represents the adult. [*See also* Case 1.]

Viviparity (*Internal Fertilization*): The eggs of sharks, chimæroids, and rays are frequently covered with a horny shell which is secreted by the walls of the egg duct. In "oviparous" sharks, such as the European Dogfish, these eggs are laid and the young, in due time, hatch out from them. In many other kinds of sharks, however, the young are long retained within the enlarged egg duct and the egg shell is either broken up or absorbed so that the young are "born alive," or released in an advanced stage of development.

Parental Care: In many cases, one or both parents, instead of abandoning their progeny to be the sport of the elements and the prey of innumerable enemies, either construct a nest, as in the case of the Bowfins and the Sticklebacks, or in some other way guard and protect the young. For example, the eggs may be deposited in some secure retreat, as in old oyster shells, or the gill cavities of clams, mussels or oysters. Among the Sea Horses, the males of certain species receive the eggs in a brood pouch of skin beneath the abdomen, where they undergo their development, while in the Cichlids, and certain Catfishes, one or the other parent takes the eggs in its mouth or pharynx and does not eat anything until the young are large enough to be released safely. In such cases, the number of eggs produced at one time may be small, since the parental care greatly improves the chances of survival for the offspring, while the eggs themselves may be large to increase the food for the young.

Adaptive Radiation in Jaws:[1] On the right of Case 53, is an exhibit showing how, in many groups, the jaws, starting with a primitive or normal type, tend to become very long and highly predacious or very short, nibbling, pinching or crushing in type.

Locomotion of Fish. [Case 54]: *Engines of the Fish's Body:* As a living, self-directing machine with a mind of its own, the fish needs all the complex apparatus shown in the models in Case 54. Its jaws, mouth, and digestive system capture and prepare its fuel. Its heart and circulatory system distribute the fuel to its engines and propellers (the muscles and the fins). By means of the oxygen absorbed by its gills from the water, it consumes the fuel, and releases the necessary energy which is expended in driving the body forward and is lost in the form of heat.

Millions of delicate sense organs are constantly recording the changes in the surrounding medium and in the position of the various parts of the body, while the nose, eyes, internal ears, brain and spinal nerve cord also act as an automatic control or steering system. Its framework, the skeleton, consists of a system of jointed levers and supports. The rear part of the hold of this living ship is freighted with live eggs.

The locomotor machinery takes up the greater part of the entire body of the normal fish. This, in brief, consists of a close-set series of zig-zag muscle segments running along the sides of the body from the head to the tail, making undulation possible. The fins act as keels, rudders, and brakes, and partly as paddles; the swim bladder as an additional balance.

Types of locomotion[2]*:* The Eel and the Trunkfish illustrate two extremely different methods of locomotion which have been named, respectively, the *anguilliform* and the *ostraciiform* types. The Eel has very numerous joints in its backbone, with an equally high number of zig-zag muscle segments on the sides of the body. By means of these, the eel throws its long, slender body into a series of small waves which pass backward faster than the fish moves forward. The Trunkfish, on the other hand, has a rigid body which swings from side to side with the sculling movement of the flexible tail.

Almost exactly between these two extremes stands the *carangiform* movement, as typified in the Crevalle or Horse Mackerel (*Caranx*). The body is short, but not rigid. The movement is essentially the same

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[1]For monograph, *see* Gregory, William King. "Fish Skulls: a Study of the Evolution of Natural Mechanisms." Trans. Amer. Philos. Soc., 1933, vol. 23, pp. 75-481. 302 figs.

[2]For detailed article *see:* C. M. Breder, Jr. "The Locomotion of Fishes." Zoologica, 1926, vol. 4, no. 5; pp. 159–297. 44 figs.

as in the Eel, except that only one large curve can be formed at a time. Movement starts by throwing the head to one side, the tail being then drawn in toward midline. The movements of the fins follow the same principles as do those of the body. Thus very long fins may be thrown into eel-like or anguilliform movement, while short, paddle-like fins recall the movement of the tail in the Trunkfish or ostraciiform type.

Streamline Body Forms[1]: Ships, submarines, torpedoes, airplanes, etc., are designed and built with "streamline" bodies which slip through the water or air with the least resistance from eddies that can be planned for under the given conditions of speed, displacement, etc. The typical fish body has streamline contours in the top, side, front, bottom, and rear views. Even aberrant body forms seem to conform to the same principle. A potent factor in determining the various streamline body forms of fishes is the universal force of gravitation which causes the pressure to increase as we descend beneath the surface of the water. The proportions of the body vary enormously in different fishes, *i.e.*, the proportion of the body length to the body height, the width, the relative size of any single part, as of the jaws or any one of the fins. Between any two extremely unlike body forms there are many intermediate conditions even among still existing species and we realize that the differences have probably grown greater with the passage of geologic time, and that such extremes have probably been derived from parent stocks of more normal shape.

[1]For further data *see:* William King Gregory. "Studies on the Body Forms of Fishes." Zoologica, 1928, vol. 8, no. 6, pp. 325–341. 35 figs.

SECTION III

DEEP-SEA AND REEF FISHES

[Case 52 and Inner Room]

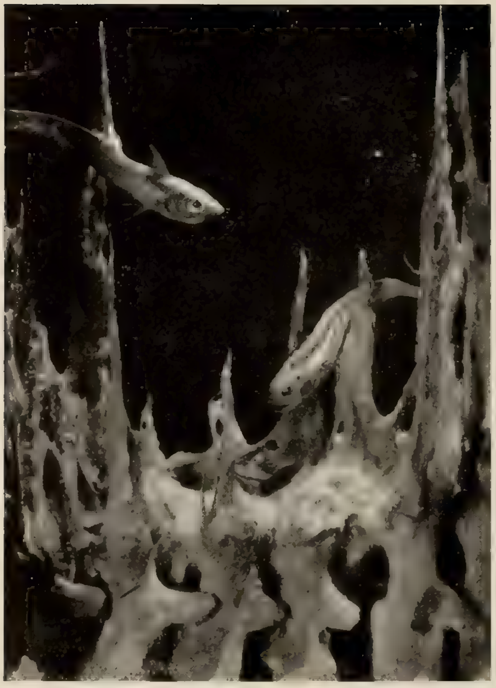

Fig. 7. Wandering Ghosts.

The walls of the inner room represent, on one side, the vividly colored fishes of a coral reef, and, on the other side, the silvery fishes of a black volcanic reef. Space in this room is being reserved for a future reef group.

The Rays and Skates shown here are discussed on pages 14 and 15.

Oarfish: Above the inner doorway, hangs the model of a rare and highly specialized deep sea fish, remarkable for its peculiar skull structure and its fragility and flatness of body in proportion to the great length. The length of body, the peculiar upturned mouth, and the crest of scarlet fin rays rising from the top near the head have supplied picturesque detail to the stories of fishermen who believed they had seen a "sea serpent" rising beside their boat.

The Sargasso Fish: This is a small exhibit showing a characteristic few inches of those miles of golden weed which stretch from south and east of Bermuda out toward Africa. Picking its way among this weed, is found the small fish known as the Sargasso Fish, *Pterophryne.*

Deep Sea Fishes: Case 52 contains enlarged models of Deep-Sea Anglers (Ceratioids). Other examples will be found in Case 35, where they are shown in their proper systematic position, and in the Deep-Sea Panels. On the northwest wall of the Hall is a case containing a model of one of these fishes, with a parasitic male fish attached to her cheek.

These strange black monsters of the deep are living fish-traps. Above or below the cavernous mouth with its long, bristling teeth, dangles a lure that in the darkness glows with a phosphorescent light. When smaller fishes draw near, attracted by this bait, they are engulfed by the large black mouth.

In some Ceratioid genera the males are free-swimming; in others they are parasitic upon the larger females and spend their lives attached to some portion of her body. In *Photocorynus* the male, two-fifths of an inch long, is attached to the top of the two and one-half inch female's head, above the right eye; in *Ceratias*, the parasitic male hangs from her cheek; parasitic males have been found attached to the abdomen of *Linophryne.*

In the outer room of the enclosure stands the old Deep Sea Group, now replaced by the Deep Sea Panels at the other end of the room. Since this old group was made it has been possible to make more accurate models of these fishes through material studied on various deep sea expeditions and investigations. A series of transparencies at one end of the room show photographs of one of these expeditions, that of the "Arcturus" in 1925, under the leadership of Dr. William Beebe and of under water exploration in the "bathysphere." In a nearby case are some of the actual specimens of these incredibly fragile fishes which live in the black depths of a mile or more under the surface of the ocean, where every square inch of their body is exposed to a water pressure of over a ton. Enlarged drawings of the same specimens are also shown here. The recently invented bathysphere,—a steel sphere with quartz windows—is so made and equipped that it has been possible for two investigators to descend in it to over 2200 feet beneath the surface of the sea. By its means Dr. Beebe has invaded the black depths in which deep sea fishes live and has seen them there with his own eyes.

The bathysphere, was first used off Nonsuch Island, Bermuda, during the summer of 1930.

Deep Sea Panels: Through the doorway underneath the Oarfish is a group of seven panels representing a descending series of zones of fish

life. The original material and data for these were, for the most part, collected by the Arcturus Expedition, in the Pacific near the Galapagos Islands. The exhibit was designed by William King Gregory and Dwight Franklin and executed by the latter with the cooperation of the Museum's Department of Preparation. The models are wax, the skins of most deep sea fishes being too flimsy to mount. The lighting of the three groups on the left (luminous fishes) is designed to first show the visitor the color and shape of the fishes, and then to exhibit these luminous fishes as they probably appear to each other in the dense blackness in which they live, only the luminous spots being visible.

Beginning at the right end of the groups, we see first the bottom of the ocean, gradually progressing until at the left end we are shown some of the fishes which live in the great depths, but occasionally come near enough the surface at night to be caught in nets.

Groups 1 and 2. "The Country of Perpetual Night," "Wandering Ghosts": These two groups show the ocean floor, 1000 fathoms down, where deep sea fishes wander about the bleached skeleton of a whale in total darkness, water pressure of over a ton, and a temperature around freezing.

Group 3. "Little Sea Devils": These are some of the small Oceanic Anglers. Their trap-like mouths are open to catch the prey attracted by the bit of luminous skin at the end of their rod-like appendages.

Group 4. "Black Pirates": These degraded eels have lost almost everything but their voracious appetites, for which their enormous mouths and distensible stomachs are well equipped. One of them has just swallowed a fish larger than himself.

Groups 5, 6, 7 (Luminous Fishes): "The Dragon Strikes" represents a group of Big Heads being pursued by a dragon-like fish, *Chauliodus*. "Blazing Jewels" shows the Jewel Fishes, flashing, luminous fishes living far down where the last feeble light from the surface merges into the blackness of the depths. "Neptune's Fireflies" shows the Lantern Fishes, rows of phosphorescent spots on their sides and head, with *Astronesthes* in pursuit.

SECTION IV

GAMEFISHES

[North end of Hall]

This collection forms the north end of the Hall and includes the results of cruises and fishing trips from Mexico to Maine and even farther afield.

A 74 lb. Channel Bass, 588 lb. Broadbill, 758 lb. Tuna, and a 2000 lb. Ocean Sunfish, looking down from the walls would seem like the answer to the fisherman's prayer:

"Lord, grant to me to catch a fish
So big, that even I
In talking of it to my friends
May never need to lie!"

In 1928, Zane Grey gave his gamefish collection of rod and reel catches to the Museum. This, with the Sailfish Group, forms the bulk of the Gamefish Section. The Sailfish in this group is the mounted skin of a fish caught off the rocky coast of Cape San Lucas, Lower California. Many other fishes well known to anglers and sportsmen, or greatly desired as closer acquaintances, hang in these cases,—Salmon, Trout, Perch, Muskellunge, Barracuda, Yellowjack, Bonefish, etc. Of the last named, we have a world record of 13¾ lb., from Bimini, Bahamas.

Dr. Grey's collection is especially noteworthy for its superb Tunas and Marlins. On the wall nearby hang colored photographs of the capture of some of these fishes and of some of his more recent Tahitian catches.

Charts of the World Record rod and reel catches hang on the wall in this section.

Fig. 8. Zane Gray and a Giant Tahitian Marlin. By permission Dr. Grey.

SECTION V

THE HIGHER FISHES

Ganoids and Teleosts

[Cases 18–38 and Groups]

THE GANOIDS, "LIVING FOSSILS"

[Case 18; groups]

Possibly three hundred million years ago, the remote ancestors of these living fossils were the Old Ganoid fishes of the Devonian period. These were, in general, shark-like forms, but with the body covered with an armor of shiny "ganoid" scales. (*See* Fossil Fish Exhibit.) Louis Agassiz, a famous American authority on fossil fishes, in 1833 classified them according to the character of their scales. His Ganoid group included all those in which the scales were covered externally with a thick, shiny, enamel-like layer (whence the name 'Ganoid,' meaning 'glistening'). Such scales were usually rhombic, or lozenge-shaped, with stratified bony tissue beneath the surface.

Each living survivor of this ancient world retains some of the features of the olden time, but has acquired certain specializations of its own. The Paddlefish of the lower Mississippi River (Group 1) retains the ancient shark-like body, but has lost most of its scales and acquired a spoonbill snout. The Sturgeon (group 2), well known commercially because of the use of its roe as caviar and of its air bladder as isinglass, also retains the shark-like form, but its mouth is sucking in type and its body covered with bony plates.

Two mounts of Russian sturgeon, from which most caviar is obtained, are shown in a northwest wall case. Only the Garpike (group 3) has inherited the complete armor of rhombic, enamel-covered scales, but its jaws are snipe-like and its skeleton completely bony. The Bowfin (*Amia*) (group 4) which is a descendant of the later, or New Ganoid, stock, is the most advanced of the series and has almost attained the rank of the Teleosts or higher fishes. This group shows the nest made by the Bowfin in which to deposit its eggs.

THE TELEOSTS

[Cases 16–36]

During the Cretaceous period, when the giant dinosaurs ruled the land, the mail-clad Ganoid fishes were largely crowded out by their more highly evolved descendants, the Teleosts, who at present constitute about ninety percent of the fish fauna of the world. The name Teleost, meaning 'completely bony,' refers to the fact that the notochord, or

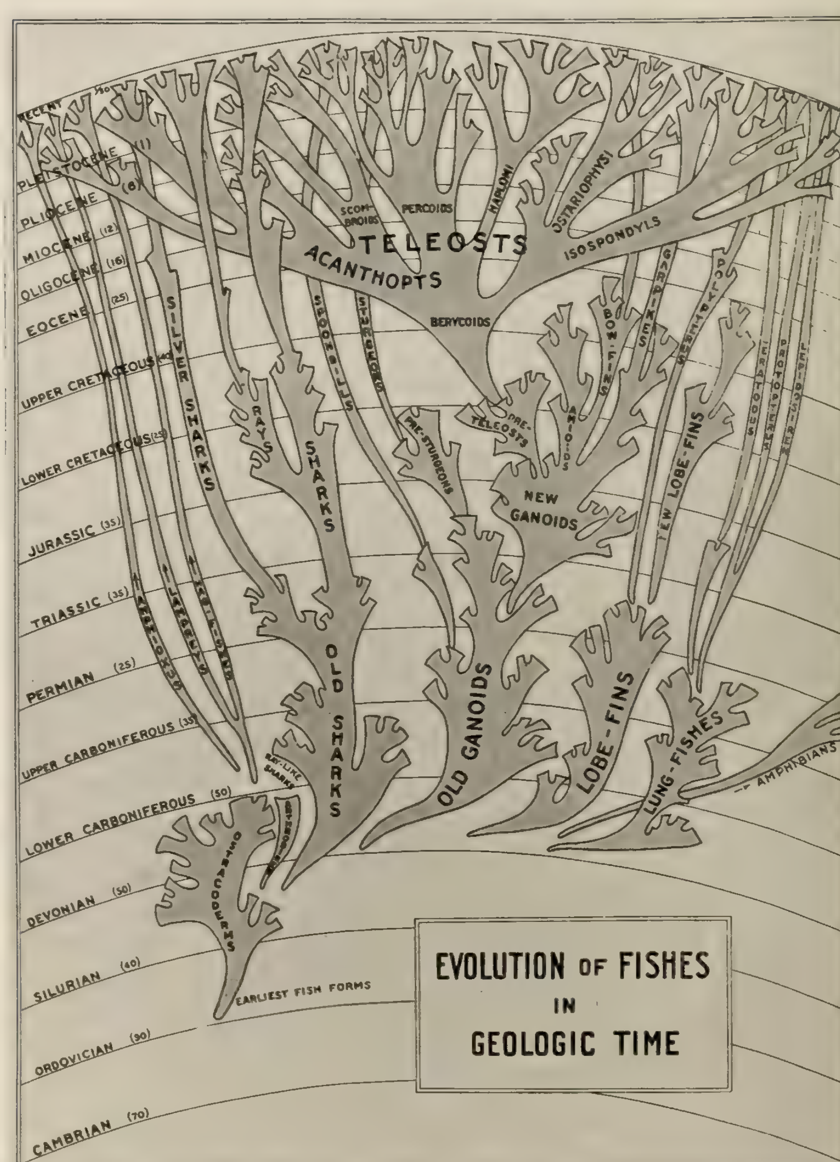

Fig. 9. Evolution of Fishes in Geologic Time.

primitive axial rod, of the larval stages of development is replaced in the adult fishes of this division by complete, bony, checker-like vertebral bodies or centra.

Order Isospondyli. (Tarpons, Herrings, Trouts, etc.). [Cases 16, 17]: This order, a main subdivision of the Teleost series, is a rather loose assemblage of fishes that are higher in rank than the Ganoids but lower than the spiny-finned fishes (Acanthopterygii). It comprises first such veterans as the Bonefish (*Albula*), the Tarpon, and the Herrings,—all survivors from the dawn of Teleost history in the Cretaceous, and, secondly, the more modernized Trouts, Salmons, etc., which are the younger scions of an ancient branch and date only from the Miocene

Fig. 10. Tarpon leaping. Drawn by D. Blakely.

epoch. Between these two divisions come the Osteoglossids, dating from the Eocene.

Beneath a great diversity of outward form, these essentially conservative fishes retain the soft or branched fin rays of the Ganoids; the air bladder retains the primitive duct that connects it with the throat, and the ventral fins are abdominal (*i.e.*, inserted under the abdomen). The name Isospondyli, meaning 'equal vertebræ,' refers to the fact that, in contrast with the fishes of the Carp-Catfish order, the first four vertebræ behind the skull are not strongly modified.

The oldest members of this order are the Leptolepidæ of the Jurassic,—small, herring-like Teleost fishes of very generalized type. Next in line come the existing Bonefishes and their Cretaceous and Eocene ancestors, while the Herrings and Tarpons follow at no great distance. The Tarpons are related to the Herrings through the fossil *Thrissopater* from the Cretaceous.

The order Isospondyli, while vastly outnumbered in species by the higher orders of Teleosts, includes a very wide range of body form, in

adaptation to different modes of locomotion, and of jaws, teeth and snouts, in adaptation to different methods of feeding.

The Elephant Fishes (Mormyridæ) are a highly specialized fresh-water group, apparently allied with the Albulidæ. These strange fishes of the River Nile were venerated by the ancient Egyptians who believed that the Mormyrids had eaten a piece of the body of the god Osiris.

The Moon-Eyes or Gold-Eyes (Hyodontidæ) are herring-like fishes of the fresh waters of North America. They stand near the common center of a number of other specialized relics of long past ages, such as the Featherbacks (Notopteridæ) of West Africa, India and Sumatra, and the Osteoglossidæ from eastern South America, West Africa and the Malay-Australian region.

The Dorab (*Chirocentrus*) of the Indian Ocean is the dwarfed survivor of a Cretaceous family that includes the gigantic *Portheus*. (*See* Fossil Fish Exhibit).

The Salmon and Trout (Salmonidæ) are the highest and most beautiful members of the soft-rayed group of fishes. They are limited to the northern world, except those that have been transplanted to New Zealand and Tasmania, and delight in cool waters, many species of trout being found in the lakes and streams that were left as remnants of the great glaciers of the Glacial period.

The Salmons are famous for their habit of coming up from the sea to spawn, travelling upstream sometimes for hundreds of miles, jumping the rapids and penetrating as far as possible toward the purer waters of the north. At the end of this journey they release the eggs and milt that give rise to the next generation and, having done so, perish by the thousands until, in Alaska, the streams are choked with their dead bodies and the sea gulls fly miles inland to feed upon them. The young Salmon, or Smolts, gradually make their way down to the sea.

Unlike their relatives the Herrings, the Salmons and Trouts are predacious fishes with strong teeth. The family, as far as known, dates only from the Miocene.

Deep Sea Relatives of the Salmon and Trout: The fantastic forms and coloring of the deep sea relatives of the Salmon and Trout (the Alepocephalidæ, Gonorhynchidæ and Stomiatidæ) are in keeping with the world of darkness and cold in which they live and rear their sensitive young. Their large eyes serve to catch the phosphorescent glow produced by other creatures, while their own light-producing organs (marked by light spots on the sides of the body) serve to attract their prey.

Order Ostariophysi. (Characins, Carps, Catfishes, etc.). [Cases 19, 20]: The members of this order are nearly all fresh-water fishes and to

this group belong most of the fresh-water fishes of the world. The Catfishes, its most specialized members, date from the Eocene epoch, so the earlier ancestral forms must be sought perhaps in the Cretaceous. Thus the group may have been derived from some very early Teleosts, perhaps the Leptolepidæ of the Jurassic.

The Weberian Apparatus: The members of this group possess one of the most remarkable of all animal mechanisms,—the Weberian Apparatus. This consists chiefly of a linked series of small, bony levers and springs which is attached at the lower end to the swim bladder and at the upper end to the back of the so-called inner ears, or organs of balance. Some authors hold that this apparatus serves to collect pulsations coming in from the water, to magnify them and to transmit them to the nerves of the internal ears. Others hold that its chief function is to transmit not sounds, but sensations of varying pressure. The small, bony levers and springs represent highly modified ribs and other parts of the first four vertebræ behind the skull. This apparatus is found in no other order of fishes.

Carps and Loaches (Sub-order Eventognathi): Everyone who has watched a living Goldfish must have noticed how it can shoot out its toothless jaws and draw in bits of food; but not everyone knows that the Goldfish, like all other members of the Carp family, carries an elaborate dental apparatus in its throat. This apparatus consists of four series of finger-like teeth located on the upper and lower pharyngeal bones, which are the rear segments of the jointed gill arches. It is to this peculiar arrangement that the name 'Eventognathi,' meaning 'wholly internal jaws,' refers.

Carps are mostly sluggish fish that feed on vegetable matter found on the muddy bottom. The carps form one of the dominant fresh-water families of Asia, Europe and North America and have undergone a wide adaptive radiation in body form as may be seen in this exhibit. To this order belongs the Bleak, *Alburnus*, the silvery substance of whose scales is used by the Japanese in the manufacture of artificial pearls. In the wall case opposite hangs a mounted skin of a giant member of this family,—the Mahseer, *Barbus tor*, or Giant Carp, found in India where it occupies probably the highest rank as a game fish.

Fossil Carps are not yet known below the Miocene of Europe.

Chinese Carps: The carps of China are related to the Suckers and Carps of North America, but whereas in the latter country the representatives of other fresh-water families are far more numerous, in China the Carps are dominant and have given rise to a great variety of forms which in external appearance recall diverse fishes of other parts of the world.

Characins (Sub-order Heterognathi): The vicious Piranha, or so-called "Man-eating Fish," forms the central type of this South American and African group. Unlike their distant relatives the Carps, the Characins are mostly carnivorous and have well developed teeth on the outer jaws, but no carp-like teeth in the throat. The name Heterognathi refers to their various kinds of jaws and teeth. They may also be distinguished from the Carps by the possession of a small adipose fin on the back, in front of the tail.

Electric Eels (Sub-order Gymnonoti): *Electrophorus electricus*, the eel-like fish from South America, is able to give a strong electric shock to any animal that touches it. Its electric organs, which fill long strips on either side of the body, represent highly modified muscle plates, richly provided with nerves. This fish is not related to the true eels, which it resembles only in general appearance, but is really an eel-like Characin.

Catfishes (Sub-order Nematognathi). [Case 20]: Catfishes for the most part are the scavengers of the river bottoms where they lurk in the mud and feed upon offal. Their scaleless, slimy bodies are covered with sensory cells that taste the food dissolved in the water. The long black barbels around their mouth doubtless aid them in feeling their way about in the semi-darkness and partly compensate for their very small eyes. The teeth in their jaws are small or lacking, and their mouth serves as a wide scoop. The maxillary, or rear upper jaw bone, is reduced to a small movable base for the main barbel (whence the name Nematognathi, meaning 'thread-jaw'). Catfishes have lost their scales, but some of them, especially the Armored Catfishes (family Loricariidæ), have acquired secondary derm bone plates covering the body. The pectoral and dorsal fins bear strong single spines which are often dangerous weapons.

Order Haplomi. (Pikes, Killifishes, etc.). [Case 21]: The Pike-Killifish order is intermediate in its anatomical characters between the Isospondyli or the lower Teleosts and the spiny-finned or higher Teleosts. The name Haplomi (simple shoulder) is given in allusion to the simplified character of the shoulder girdle which lacks the "mesocoracoid" arch, or middle inner brace of the bony base of the pectoral fin. This structure is possessed by all Ganoids and lower Teleosts in which the pectorals are held in a more horizontal plane, but is lost in the higher Teleosts in which the resting pectorals are held in a more vertical plane.

The Pikes and Pickerels which are the typal forms of this order, lie in wait for their prey and make swift rushes to snap it up with their long, sharp-toothed jaws. Their whole appearance is in keeping with their piratical life. Their small relatives, the Killifishes, are chubby caricatures

of the Pikes, with tiny mouths instead of gaping jaws, but they retain the pike-like backwardly placed dorsal and anal fins, and broad tails that enable them to make very quick turns.

Several members of the Killifish family have been successfully used in destroying mosquitoes.

ORDER INIOMI. (Lizardfishes). [Case 21]: These large-mouthed, needle-toothed fishes are in certain respects intermediate between the Salmon-like forms of the soft-rayed order and the Pikes and their allies of the order Haplomi. Many of the deep sea members of the family (Myctophids) have a series of light-producing spots on the body and head. These light organs, which are described in other exhibits, have been developed independently in different groups of deep-sea fish.

In some of the Lizardfishes that live at great depths, *e.g.*, *Bathypterois*, the eyes are reduced or absent, while the rays of the breast fins are prolonged into delicate feelers. The family is an ancient one, dating from the Upper Cretaceous period.

ORDER HETEROMI. (Halosaurs). [Case 21]: These distant relatives of the isospondyls reveal their deep sea habit in the combination of very dark colors, eel-like form with very long tapering tail, and small eyes. Only the lower part of the tail fin is developed.

ORDER THORACOSTRACI. (Sticklebacks, Tubefish, Seahorses.) [Case 21]: This order includes a number of very peculiarly formed fishes.

The Sticklebacks (Gasterosteidæ): These fishes are so called because of the three isolated spines which represent the spinous dorsal. The small two and three-spined Sticklebacks can be moved from fresh to salt water or vice versa without harm. The larger fifteen-spined *Spinachia* is entirely marine. The male fish builds the nest of weeds, held together by a thread-like secretion from the kidneys, and then guards the eggs deposited by the female. These fishes are short-lived and probably only breed once.

Fishes with Tubiform Snouts. (Aulorhynchidæ, Aulostomatidæ, Centriscidæ): These fishes have elongate bodies and produced, tubiform snouts. The Aulorhynchidæ are closely related to the Sticklebacks. Their elongate snouts approach those of the Trumpet Fishes, or Aulostomatidæ, of the West Indies, Polynesia and Asia. A species of *Aulostomus* is found in the Eocene of Italy. The Shrimp Fishes, Centriscidæ, possess a transparent bony cuirass covering their back and extending beyond the tail. The small, toothless mouth is at the end of a long snout.

Fishes that Swim Vertically. (Amphisilidæ, Syngnathidæ): The Syngnathidæ, including the pipefishes and seahorses, are more or less

elongate, and protected by an exoskeleton forming rings. The snout is somewhat produced and tubiform and the tail sometimes prehensile. In most species, the male takes charge of the eggs in a pouch under the tail or on the abdomen. (*See* p. 21.) The Australian Seahorse, *Phyllopteryx*, is remarkable for its seaweed-like appendages. The Northern Seahorse is common to our coast in summer, from Charleston, South Carolina to Cape Cod, Massachusetts. Where it goes in winter is as yet unknown.

Like the Seahorses, the Amphisilidæ swim vertically. There are three or four species of this family, found in the Pacific and Indian Oceans. The body is much compressed and completely enclosed in a thin, bony armor which is fused with the endoskeleton.

ORDER APODES. (The Eels). [Case 22]: The Eels have cast aside all superfluous fins, drawn out the smooth cylindrical body into a compressed tapering end, and multiplied the muscle segments until they can undulate as easily as a streamer waves in the wind. (*See* p. 22.). In some families of Eels, the scales are entirely lacking, but in the most common eel, *Anguilla*, they are present, although rudimentary and imbedded.

The true Eels of Europe and America all go to the deep sea to spawn. There is one area south of Bermuda where all such Eels have been thought to spawn, and certainly they seek either this or similar ocean conditions. The eggs hatch flat, translucent, un-eel-like larvæ known as Leptocephali. These are so unlike the adult that they have sometimes been classified as distinct fishes. Those to the westward gradually drift, as they grow, toward America; those to the eastward toward Europe. When they approach the shore, they are several inches long. On entering coastal waters they shrink to a smaller size and take on the appearance of Eels, though still more or less transparent. Some of these remain and grow in coastal salt or brackish waters, and others penetrate far inland becoming the Fresh-water Eels of the interior.

The Conger Eel does not enter fresh water; it moves away from the shore to spawn but it too dies after spawning.

The Morays are typically reef fishes. They are the largest of the Eel tribe and have powerful jaws armed with sharp teeth.

ORDER SYNENTOGNATHI. (Flying Fishes, Needlefishes, etc.) [Wall Case]: Several unrelated groups of fishes have developed independently the ability to fly, but the Exocœtidæ, or Marine Flying Fishes, characteristic of the trade wind belts of open, tropical oceans, excel all others in aërial powers. These, of all flying animals, most closely re-

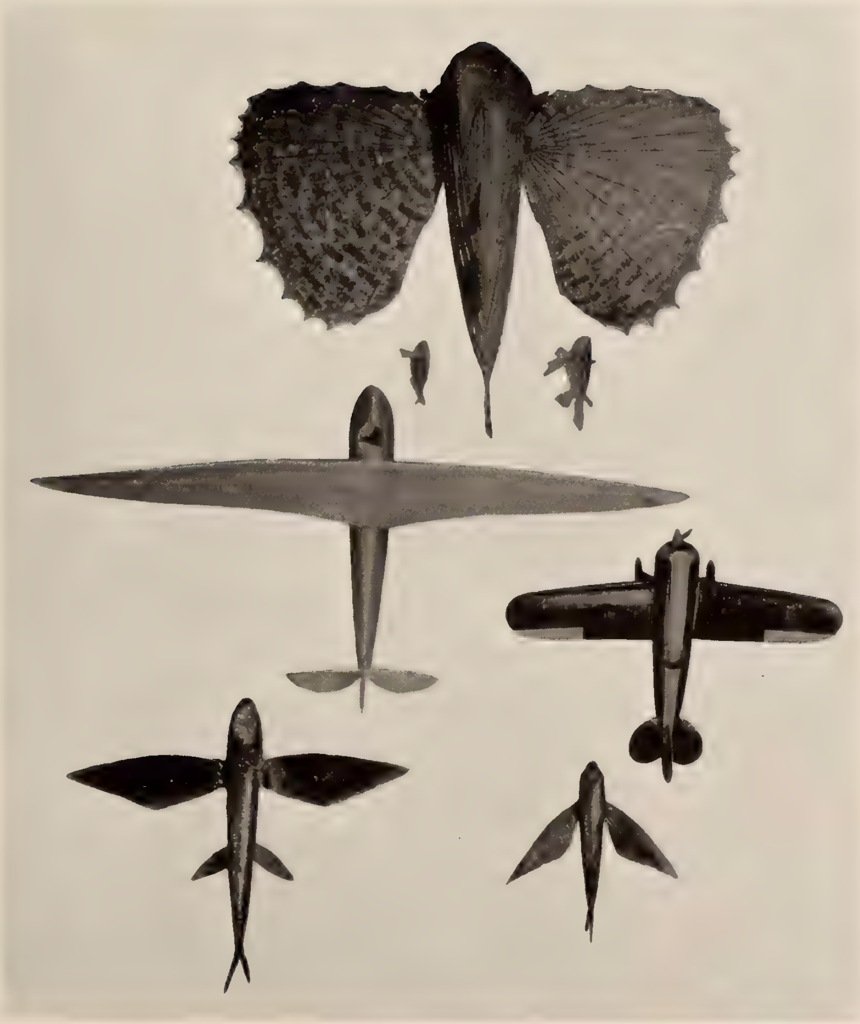

Fig. 11. Flying Fish and Airplane Compared.

semble the modern airplane. The proportions of flying fish and air plane are very close in spite of the disparity in size.

Being an organic unit and not a rigidly articulated machine, the fish is capable of greater flexibility of movement and possesses some adjustments not yet possible in a plane.

The camber of the wings, their placement and the presence of stabilizer fins at their proper places, considering the form, size and landing requirements of each, are remarkably similar. One of the most striking differences is the complete absence of any landing gear on the fish. This is a notable economy, possible because the fish can plunge into the water head-first or drop without injury in a manner that would wreck a plane.

The average rise of these fishes is about five feet, although they occasionally rise higher; the length of flight varies from fifty to three hundred feet, and, when with the wind, has been observed to attain a quarter mile. Turning is accomplished by use of the body muscles and tail fin. The wings, when in flight, remain like the wings of a glider. The larger the fish, the longer the flight will be and the fewer the dippings of the tail into the water for added power.

About twice as many flying fishes fly in schools of two or more as fly alone. *Parexocœtus mesogaster* is the predominant form in the Gulf Stream.

The Flying Fish group appears to be an offshoot from some early member of the spiny-finned order.

Other Flying Fishes: Three other fishes not related to the Synentognaths have powers of flight. These are:

The South American Fresh-Water Flying Fish (*Gasteropelecus*), a small fish related to the Piranha of the family Characinidae. This fish is able to make a flight of from five to ten feet.

The African Fresh-Water Flying Fish (*Pantodon*), a small Isospondyl related to the Herring-Trout group. This fish has very slight powers of flight.

(?) *The Flying Gurnard* (*Dactylopterus*), one of the mail-cheeked fishes, related to the Sea Robins and Sculpins. The Flying Gurnard has been said to leap into the air, where its relatively large breast fins are able to support it for a short journey.

Order Percesoces. (Barracuda, Mullets, etc.) [Case 27]: The Barracuda (*Sphyræna*) is one of the most piratical looking of all sea-going crafts, and its record of attacks on human beings justifies its evil reputation. While in general appearance it recalls the Pikes, it may be recognized readily by its separate spiny dorsal fin. This fin is also possessed

by such peaceful kinsfolk of the Barracuda as the Silversides (Atherinidæ), and Mullets (Mugilidæ). The latter feed on other small animals, algæ and occasionally vegetable matter. They resemble the Flying Fishes in the high position of their breast fins, and the group as a whole may be distantly related to that assemblage.

Order Acanthopterygii. (The Spiny-Finned Fishes.) [Cases 24–36]: The vast majority of existing species of fishes belong to the "spiny-finned" order, the peculiar features of which are illustrated in the skeleton of a Striped Bass. The word 'spiny-finned' is a translation of Acanthopterygii. The first few bony rays of the dorsal fin are tipped with sharp points and there are also such points on the first ray of the pectoral and ventral fins and on the first few rays of the anal fin.

The typical spiny-finned fish has a fairly stout body with a broad strong tail base and broad tail,—all signs of vigorous swimming ability. The pelvis or bony base of the ventral fins is prolonged forward and fastened between the ploughshare-like lower end of the pectoral girdle. This arrangement facilitates quick turning and stability. These fishes usually have strong jaws and teeth, and prey upon other fish. The front upper jaw bone (premaxilla) is prolonged backward and downward so as to shut out the second upper jaw bone (maxilla) from the corner of the mouth. The maxilla is thus toothless and acts only as a lever for pushing forward the premaxilla.

The bony operculum, or chief gill-cover, usually has a point or spike on its hinder end. The supraoccipital bone usually forms a prominent crest above the back of the skull. To this crest on either side are attached the muscles that run along the top of the back.

The skull forms a strong wedge which is pushed through the water by the forward thrust of the backbone. The skull may also be considered as the pivot upon which the body is thrown into waves. Even without the tail fin, the fish can move forward by waving the body. The tail fin serves both as a flexible paddle and as a rudder. The other fins serve as keels, brakes and rudders.

The Basses and their Allies: (Sub-Order Percoidei). [Cases 23, 24, 25]: The true Basses (Serranidæ) and their allies stand near the center of the great assemblage of spiny-finned fishes. They are mostly stout-bodied fishes, usually swift and voracious. Most of them prey upon smaller fishes, crabs, shrimps and other crustaceans. Many are brilliantly colored and some, such as the Rockfishes, can change their colors to suit the color of their background.

Snappers, Grunts and Porgies. [Case 23]: The Snappers (Lutianidæ) are carnivorous food fishes, closely allied to the true Basses, but often having a longer face from the tip of the upper jaw to the lower border of the eye. The back part of the upper jaw slips under the lower border of the enlarged front suborbital bone and is thus concealed when the mouth is closed. Above the ventral fins there is often a scaly flap. These fishes are usually very brightly colored.

The Grunts (Hæmulidæ) are also called Roncos, from the Spanish word, *roncar*—to grunt or snore, referring to the noise they make either with the very large pharyngeal teeth or the complicated air bladder. These also are tropical fishes.

The Porgies (Sparidæ) are well known in our markets through the Northern Porgy, commercially called Porgy. In these fishes, the pharyngeal, or throat, teeth become very large, and in one form, the Sheepshead, the front teeth of the upper and lower jaws are also strongly developed so that with them the fish can pluck up crustaceans which are then crushed by the teeth in the throat. The Porgies occur chiefly in warm waters and many of them are vividly colored, the common Mediterranean species being crimson with blue spots.

The Basses. [Case 24]: The true Basses (Serranidæ) include the Sea Bass, Striped Bass, White Perch of this vicinity, the Rockfish and the Groupers of the Florida Keys and Cuba, besides many others in various parts of the world.

Most of these have three well developed spines in the anal fin, and the back part of the upper jaw is quite distinct when the mouth is closed. The upper corner of the gill cover often has one or two spines.

Fishermen apply the name Bass indiscriminately to bass-like fishes belonging to other families as well as to the fishes above named, such as the Large-mouth Black Bass and the Small-mouth Black Bass, both of which actually belong to the Sunfish family (Centrarchidæ), and the Channel Bass and California Sea Bass which belong to the Weakfish family (Sciænidæ).

The White Perch (*Morone*) is not, strictly speaking, a Perch at all, but a Bass.

The Perches and Darters. [Case 24]: These fishes of the family Percidæ have more joints in the backbone than the Basses and differ in other ways.

The Bluefishes (Pomatomidæ). These are swift, carnivorous fishes which approach the Mackerels in appearance.

The Triple-tails (Lobotidæ) are powerful, deep-bodied fishes.

The Berycids are chiefly deep sea forms, near relatives of the Squirrel Fishes.

Croakers and Weakfishes. [Case 25]: The Croakers (Sciænidæ) are closely related to the true Basses, but differ in their small anal fins in which the spines are reduced. In the long dorsal fins there is a deep notch between the spiny and soft parts, but the two are in contact at the base. A system of large pits on the top of the skull lodges sacs containing the sense organs of the lateral line system.

Local members of this marine family are the Weakfish, Channel Bass, Spot, Croaker, Kingfish (*Menticirrhus*), and Sea Drum. The latter has strong, paved teeth in its throat for crushing shellfish and makes a loud grunting sound with them.

Crab-Eaters, Shark Suckers, etc. (Sub-order Discocephali) (Case 25]: This sub-order includes the Crab-eater, Cobia, and the Shark Sucker, *Echeneis.* The latter has an adhesive disc on top of its head, by means of which it is able to cling to the sides of larger fishes, particularly the sharks.

Fig. 12. Galapagos Angelfish. From painting by W. Belanske. From W. K. Vanderbilt collection of scientific paintings of fishes caught from his yacht, the Ara.

Angel, Butterfly and Surf Fishes. (Sub-Order Squamipinnes). [Case 27]: The Angelfishes (*Holacanthus, Pomacanthus, Angelichthys*) and their relatives the Butterflyfishes (Chætodontidæ) have small, nibbling mouths which act like pincers in plucking off small living organisms from the rocks and coral reefs. The great depth of the body and the strength of the fins give the fish a very firm stance and power in

plucking. The brilliant or dense colors are in wide contrast to the pale or silver hue of open-sea fishes. In the Butterfly Fishes, the teeth are very fine and brush-like.

The Viviparous Surf Fishes. (Embiotocidæ): The Surf Fishes are deep-bodied offshoots of the Bass stock which develop the young within the body of the mother. This is very unusual among Teleost fishes.

Fighting Fish, Climbing Perch and Snake Heads. (Sub-Order Labyrinthici). [Case 27]: The Labyrinthici are so-called because of the peculiar structure of the pharyngeal bones and respiratory apparatus. In these labyrinth-gilled fishes, the gill filaments discharge their normal function, but in addition, the fourth branchial arch is extremely developed and provided with thin folds forming chambers in which air is retained for respiration.

Betta pugnax, the Fighting Fish of Siam, is said to be used by the natives in the same way cocks are used for cock fights, only in this case the combat takes place in a glass aquarium bowl. The various species of this genus are popular as aquarium fishes, more because of their extremely bright and beautiful colors than because of their pugnacity.

The Climbing Perch, *Anabas scandens*, has been credited with the ability to climb trees. This is an exaggeration, but the fish is able to move rapidly overland by means of the mobility and sharp spines of its gill cover, aided by its strong pectoral fins and tail. *Channa*, the Snake-head Mullet, is a native of Ceylon and China.

The Osphronemidæ (Snake-heads) have not such a complicated accessory breathing structure as the others and are probably degraded descendants of the Labyrinthici.

Abudefdufs and Cichlids. (Sub-Order Chromides). [Case 28]: The strange name *Abudefduf* is Arabic in origin, coming from two words meaning literally, 'father,' and 'side' or 'flank,' *i.e.*, something with prominent sides. These jolly little fishes of the coral reefs are always bustling about after the small pickings on which they feed. They are related to both the Cichlids and the Wrasses, and, like them, have crushing teeth in the throat.

The Cichlids are especially plentiful in Lake Tanganyika, Africa. They are small relatives of the Wrasses and have invaded the brackish and fresh waters of Africa, Madagascar, Syria, India, Ceylon, South America and Central America, and as far north as Texas. The duty of caring for the eggs and young is performed by the females in certain species; in others, the males take over this responsibility. In either case, the eggs and young are sheltered in the mouth or in the pharynx of the self-denying parent who is necessarily deprived of food until the young are able to take care of themselves.

Wrasses and Parrot Fishes. (Sub-Order Labroidei). [Case 28]: Apparently nature grew reckless when she colored the Wrasses and Parrot Fishes, for these are among the most bizarre sights that bewilder the eye of the visitor to undersea gardens in tropical waters. Only the Cunner and the Tautog, among the northern outliers of the family, have been toned down into sobriety and sombreness in the chill waters of New England. The Cunner retains the loose, protruding lips and retreating forehead of its tropical ancestors, but the Tautog has acquired a short stiff mouth, a prominent chin and a generally determined countenance.

The Wrasses are more or less omnivorous, nibbling and biting with their strong incisors and crushing with the remarkable pebble-coated millstones in their throats. In the Parrot Fishes, the front teeth have fused into a large, nipper-like beak, while the mill in the throat is surmounted by cylindrical teeth of oval or flattened section. The origin of this apparatus may be traced to the simple conical teeth clustered on the surface of the gill skeleton in primitive Wrasses. In leisurely swimming, many of the Wrasses and their allies use chiefly the pectoral fins, holding the large tail fin as a rudder.

Sculpins, Gurnards, Scorpion Fishes, etc. (Sub-Order Scorpænoidei). [Case 29]: This group of fishes is generally known as the Cheek-Armored Fishes, in reference to the fact that one of the bones surrounding the eye is much enlarged and arches backward over the cheek so as to gain a broad contact with the forepart of the bony gill cover. Thus it forms the so-called "bony stay" that strengthens the skull in this group.

The Gurnards, or Sea-Robins, with their broad heads enclosed in this bony shield, bear little resemblance to the Basses, yet the Sculpins and the Rose Fishes tend to connect them with the primitive Sea Bass stock.

Most of the fishes of this group are marine forms, living either among the rocks, or on or near the bottom, sometimes at considerable depths. The most primitive forms are the Rose Fishes; the most advanced the Flying Gurnards.

The Gurnards have the first three rays of the breast fins specialized as 'legs.' Due to this specialization, their movement among seaweed or along any surface much resembles walking on these fins.

In the Lumpfishes and Sea Snails, the ventral fins are modified into a sucker, by means of which these fishes cling to the rocks.

In the Platycephalids, the flattened head presents a curious resemblance to that of bottom-living forms of widely different groups, such as the extinct Ostracoderms (*see* Fossil Exhibit), and the Armored Catfishes (case 20).

The Gobies. (Sub-Order Gobioidei). [Case 29]: The Gobies have pushed their way into all the seas outside the Arctic and Antarctic circles, and have representatives in the fresh waters of all parts of the world. The central form, *Gobius*, is not very different from the Johnny Darters of the Perch-Bass group, except that the ventral fins together tend to form a sucking disc by means of which the fish clings to rocks. In the Mud Skipper, *Periophthalmus*, the breast fins are modified into flippers and the fish skips about on these over the mud flats of

Fig. 13. *Periophthalmus*, the Mud-Skipper. Drawn by D. Blakely.

eastern tropical rivers. Its eyes are greatly enlarged and protruding. In the Blind Goby of California, on the other hand, the eyes are reduced to mere vestiges and the fish lives like a slug under the rocks.

In size the Gobies vary from the minute *Mistichthys* of the Philippines, which measures only twelve to fourteen millimeters in length, to the *Eleotris marmorata* of Siam, which grows to nearly three feet. The Gobies differ from the cheek-armored group in lacking the bony stay of the cheek.

Cods, Hakes, Rat-tails, etc. (Sub-Order Anacanthini). [Case 30]: These mulluscous, obese offshoots of the vigorous spiny-finned order are

highly specialized, and in many respects degraded. Even in the rat-tailed Grenadiers (Macrurids) which are less specialized than the Cods, the true tail fin has been lost and the hind end of the body has been prolonged into a trailing wisp. In the Cods and their allies, the tail, while outwardly not unlike that of more normal fishes, appears to be merely an imitation, fashioned from the rear parts of the elongated, subdivided soft dorsal and anal fins, as shown by the construction of the bony rods supporting the tail. In the Grenadiers and Cods the ventral fins are normal, but in the Hakes they have been reduced to greatly elongate feelers.

This group as a whole is essentially marine and ranges from the greatest depths to the shallower waters of the coastal belt. The abundance of these fishes is truly astounding. For example, 14,000,000 pounds of Silver Hake were marketed in Massachusetts and Maine in 1919. As to their fertility,—the roe of a seventy-five pound Cod contained, according to a careful estimate, no less than nine million, one hundred thousand eggs.

Long before the landing of the Pilgrims at Plymouth, boats had come from Europe to the New England coasts and north to the Grand Banks to fish for cod. These fisheries, which have now been developed into a huge industry, were of the utmost economic importance in the life of the early settlers in New England. They center at present in Boston and Gloucester, Massachusetts. The Cod fisheries are also a big industry in France which sends a large fleet to the Iceland fishing grounds, and in Norway which carries on big fisheries in the Lofoten Islands.

Blennies. (Sub-Order Blennioidei). [Case 30]: The Blennies are active little fishes living around rocky or coral reef shores. Certain Blennies, for instance the Lizard Skipper of Samoa, even leap from rock to rock at low water, in this respect parallelling the unrelated mud-skipping Goby. Most of them are small, but there is one gigantic and ferocious-looking marine Blenny, with strong tusk-like front teeth. This is the Sea Wolf, *Anarrhichas.* It also has large, rounded crushing teeth on the roof of the mouth and inner side of the jaw, enabling it to devour crabs and shelled molluscs.

The Eel-Pouts are elongate derivatives of the Blenny stock.

The Weavers. (Sub-Order Jugulares). [Case 30]: The Weavers are distant relatives of the Perch-like fishes. Some of them have poisonous spikes on the gill-covers. The Electric Star-gazers of this group have a pair of powerful electric organs behind the eyes.

Mackerels, Tunas, Dolphins, etc. (Sub-Order Scombroidei). [Cases 31, 32, 33]: The Mackerel group represents one of the culminating phases in the evolution of the Bass-like fishes from which group its more

typical members are distinguished by the torpedo-like body, the delicate, thin-boned skull, absence of spines on the gill cover, reduction of the scales, presence of a horizontal keel at the base of the tail, and the symmetrical arrangement of rear fins above and below the horizontal axis.

Pedigree of the Mackerels and their Allies. [Case 31]: This Sub-Order divides itself into four principal lines: (1) The Mackerel Series, culminating in the Albacores and Bonitos. These are the swiftest and most active of all the Mackerels, with beautifully streamlined bodies. (2) The Spanish Mackerels and Wahoos, chiefly distinguished by their pointed snouts, their long, low body and long dorsal fin. (3) The Swordfish and Sailfish in which the forepart of the skull is produced into a long, sharply pointed beak. In the Sailfishes, the dorsal fin is of enormous size. (4) The Escolar-Cutlass Fish line which runs out into fierce eel-like forms.

Bonitos, Tunas and Mackerels. [Case 32]: The acme of speed, of "fineness" and of streamline form is attained by the Bonitos, Tunas, Mackerels and their allies. In the Bonitos and Tunas the body is short and comparatively stiff; the tail large and lunate but with a slender, strong base. These fishes often leap from the water like Dolphins, or like a projectile that strikes and ricochets from the surface. In the Mackerels the body is more elongate and torpedo-like, with forked tail. In the Cutlass Fishes, the body has become eel-like and the tail is reduced to a point. The Oil Fish, *Ruvettus*, a deep-sea relative of the Mackerels, is here shown with the wooden hook used for its capture in the South Seas.

Dolphins, Pompanos, Moonfishes. [Case 33]: The central type of these pearly, silvery fishes is the Pompano, from whose orb-like body we may derive, on one hand, the much deepened disc of the Moonfish and Lookdown, and, on the other, the progressively elongate form of the Jacks, or Amberfishes.

The ornate Roosterfish may be regarded as an Amberfish with an enlarged and plume-like first dorsal fin. The Dolphin (*Coryphæna*), another long-bodied offshoot of the Pompano stock, is famous for its brilliant and changing blue and golden hues. The Dolphin of heraldry and sculpture is a composite of this fish and the true Dolphin which is a kind of porpoise or toothed whale.

In the wall case opposite this alcove is a cast of the Opah or Moonfish, *Lampris luna*, a round, iridescent fish with scarlet fins, a very rare visitor on our coasts. This fish reaches a length of six feet and a weight of five hundred to six hundred pounds.

Flatfishes. (Sub-Order Heterosomata). [Case 38]: In this group belong the Flounders, Halibuts, Turbots and their allies,—fishes which habitually lie on one side on sandy bottoms. They have been derived

from deep-bodied fishes allied to the John Dory (*Zeus faber*). The oldest known member of the group, *Amphistium* of the Upper Eocene, was a deep-bodied, symmetrically built form which had not yet become twisted for lying on its side.

It is to this group that the Soles belong. The "filet of sole" of American restaurants is usually made of the Winter Flounder, *Pseudopleuronectes americanus*. The European Sole belongs to the same family as the American Sole, but none of the American species are particularly valued as food.

Migration of the Eye in Flatfishes: When the Flatfish are hatched, the young are normal in appearance, with even coloration and an eye on either side. They swim in a normal, fish-like way. However, as the fish begins to develop, it tilts over toward one side, and finally becomes adapted for resting and swimming in this position. One result of this is that the color on the more exposed side grows deeper, while that on the under side remains light. Meanwhile, the eye of the down-turned side migrates over the top of the skull, so that, in the adult, both eyes lie on the upper side of the head. The mouth also is partly twisted onto the upper surface.

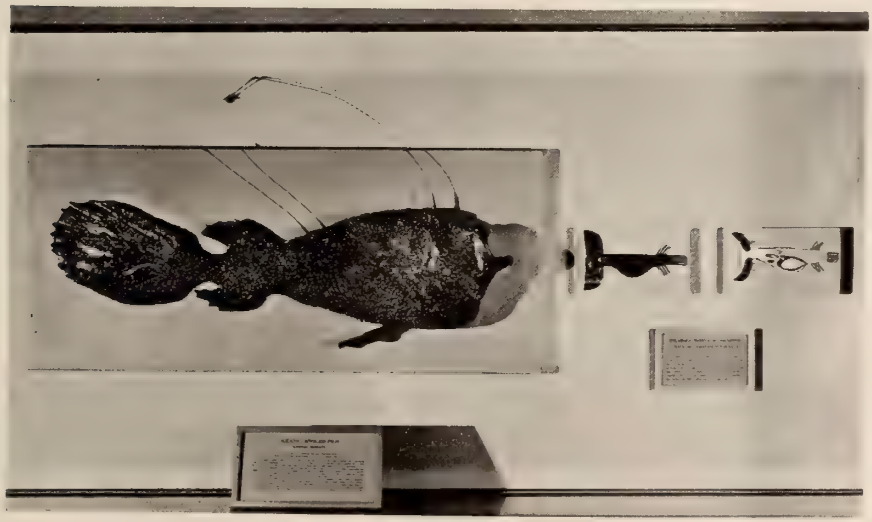

Fig. 14. *Ceratias*, the Oceanic Angler and Parasitic Male.

ORDER PEDICULATI. (Anglers, Batfishes, etc. *See also* Section III). [Case 35]: The terrible living trap set by the Angler Fish lies concealed in wait for the unwary fish that stops to examine its dangling bait.

This trap consists of the sharp-toothed jaws and cavernous interior of its enormous mouth, and the bait is a bit of skin floating from the top of a movable fishing rod which is made from an enlarged and separated ray of the dorsal fin. In the Oceanic Deep Sea Anglers (Ceratiidæ), living in abyssal darkness, the "bait" becomes luminous.

The males in several species of Oceanic Anglers are of extremely small size and live dangling like pendants from the side of the head of the gigantic females. An exhibit in a window case shows a replica of a cast in the British Museum (Natural History) of *Ceratias holboelli*, the Oceanic Angler, with its parasitic male. We quote from the original British Museum label:

"The female Angler Fish with attached parasitic male from which the original cast was made, was taken near Iceland. It is 40 inches long and has a male 4 inches long attached in the mid ventral line a little behind the head. Unlike the female, the male has no fin ray on the head; its mouth is small, toothless and closed in front, and the alimentary canal is vestigial. Fleshy outgrowths from the face of the male unite in front of the mouth and fuse with a projection from the skin of the female. Dissection reveals that both the outgrowth from the male and the projection from the female are formed of fibrous tissue with numerous small blood vessels. The union is complete so that it is impossible to say where one fish begins and the other ends. The blood system appears to be continuous with that of the female, from which the male derives its nourishment. The Ceratioids are unique among backboned animals in having dwarfed males of this kind."

The habits and conditions of life of the Ceratioids—few in numbers, solitary, slow swimmers, floating about in the darkness of the middle depths of the ocean—would make it difficult for a mature fish to find a mate. It is probable that the males, as soon as they are hatched, when they are relatively numerous, see the females and if they find one become attached to her and remain attached for life. Probably the male first nips a piece of skin of the female, and then its lips fuse with the papillæ so formed.

In the Batfishes the body is flattened and the fins serve as limbs for moving about on the sea-bottom.

The Angler group may be regarded as excessively specialized relatives of the Blennies [case 30], the Toadfishes being in some respects intermediate between the two groups.

Order Plectognathi. (Puffers, Trigger Fishes, etc.). [Cases 35, 36]: This group as a whole appears to be derived from the stem of the Trigger Fishes.

The Puffers and Porcupine Fishes. [Case 35]: The frog that tried to swell to the size of an ox finds a certain parallel in the Puffers (Tetrodontidæ) and Porcupine Fishes (Diodontidæ), which, however, unlike the frog, do not burst, but readily deflate themselves before their elastic limit is reached. They puff themselves out by pumping in water through the mouth by means of the action of certain specialized muscles behind the enlarged shoulder plates. Apparently it is as hard for a larger fish to bite an inflated Puffer as it is for a boy to bite an apple floating in the water. In both the Puffers and the Porcupine Fishes, the fore part of the jaws are modified into powerful nippers for biting and crushing resistant objects. In the Puffers the beaks of the opposite sides are separate; in the Porcupine Fishes they are fused together.

The Ocean Sunfish (*Mola*), of which there is a large specimen in the Gamefish section, is a gigantic relative of the Porcupine Fish. It is a slow-swimming, lethargic fish, fond of coming to the surface of warm waters to sun itself, and easily caught.

The Trigger Fishes. [Case 36]: The Trigger Fish is an inoffensive fish which goes bustling around the coral reefs searching for something good to nibble, but if a larger fish attempts to swallow him, he erects his tall spike, stretches his leathery skin and awaits developments. His "trigger" is the small spike on his back, lying behind the large one. When it is pulled into place by the muscles beneath, it serves to lock the larger spike in an erect position so that the latter cannot be lowered until the trigger is withdrawn. The Triggers are more specialized relatives of the Surgeon Fishes.

The Surgeon Fishes. [Case 36]: The Surgeon Fishes, or Xesuri, are so called because they carry sharp knives, one on either side of the base of the tail. These actually represent a greatly enlarged scale which is sometimes depressible in a case or groove. The fish seems to be able to give a vicious "side swipe" with its tail.

In *Xesurus* and related genera, the knife is replaced by three or more forwardly-directed spikes. Probably the 'knife' of the true Surgeon Fishes represents a specialized survivor of one of these three spikes.

The group as a whole constitutes a specialized offshoot from the stem of the Butterfly and Angel Fishes.

THE BASHFORD DEAN MEMORIAL EXHIBIT
OF
FOSSIL FISHES

Southeast Pavilion
Fourth Floor

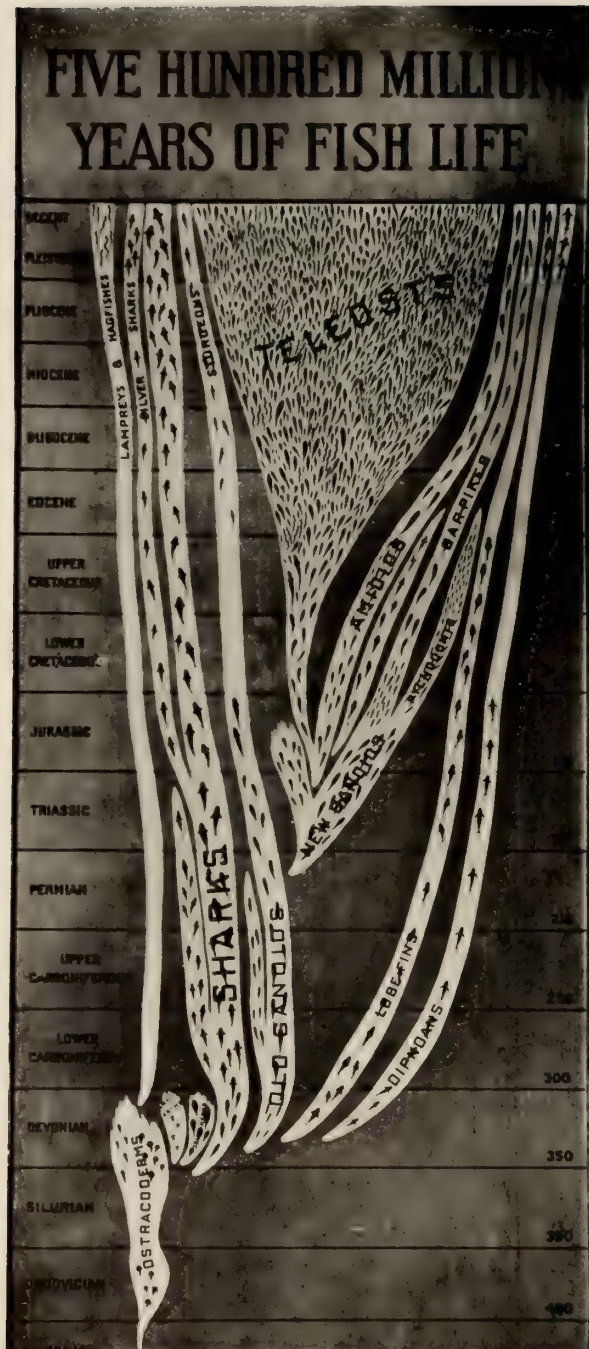

Fig. 15. Five Hundred Million Years of Fish Life. Chart drawn by W. Benckert.

THE BASHFORD DEAN MEMORIAL EXHIBIT OF FOSSIL FISHES

Southeast Pavilion
Fourth Floor

This exhibit of Fossil Fishes was rearranged in 1929 as a memorial to Dr. Bashford Dean (1867–December 1928), first Curator of the Department of Fishes in this Museum; later its Honorary Curator; always its friend and contributor, and author of many authoritative works on fishes living and fossil.

The bronze portrait plaque of Dr. Dean, hanging to the right of the entrance, is the memorial gift of friends and colleagues in America, Europe and Asia. Below is a small case containing a monograph by Dr. Dean, one of his field notebooks and a letter from him written from Japan to his friend and colleague Professor Henry Fairfield Osborn.

On the left of the entrance is a bronze portrait plaque of Professor John Strong Newberry (1822–1892), professor of geology at Columbia College; well-known for his studies on the fossil fishes of the Devonian, and the friend and teacher of Bashford Dean. His collection, the property of Columbia University, is deposited in this museum.

The fossil fish exhibit consists of selected material from the museum's large study collection. It includes parts of the following collections as well as important single specimens:

Newberry Collection: deposited by Columbia University in 1903. Brought together by Professor J. S. Newberry. About 3350 specimens.

Cope Collection: presented by the late president of this Museum, Morris K. Jesup. About 2425 specimens.

Dodge Collection: presented by William E. Dodge. About 100 specimens of Placoderm fishes from Ohio, collected by Mr. Jay Terrell.

Day Collection: presented by Rev. D. Stuart Dodge. About 1200 specimens collected in the Cretaceous of Syria by the late Dr. Alfred Ely Day.

Hall Collection: brought together by Professor James Hall. About 250 specimens.

Stuart Collection: presented by Robert L. Stuart. 40 specimens.

Kepler Collection: 75 specimens of Placoderms and primitive sharks, collected in Ohio by Rev. William Kepler and purchased by the Museum in 1904.

American Museum Collection: specimens collected in the field by various expeditions, and otherwise obtained by purchase, gift, exchange, etc.

NOTE: The guide to this exhibit is based on the explanatory labels found in each case.

FIVE HUNDRED MILLION YEARS OF FISH LIFE

[Wall Chart, Case 11]

The class of Fishes was the first of the vertebrates to appear in the history of the earth, fragmentary fossil remains of Ostracoderms having been found in rocks of the Lower Ordovician Age near Canyon City, Colorado.

According to the most recent geological estimates, the age in years of these rocks would be about four hundred million years. It is not improbable that even in the Lower Cambrian (five hundred and fifty million years) the predecessors of the Ostracoderms were already distinct from the trilobites, worms, molluscs and other animals of that far-off time. This chart represents in a general way the main branches of fish life as indicated by fossils from successive geological horizons.

Sequence of Fishes in Geologic Time. [Case 11]: Many hundreds of extinct species of fishes are already on record. Nevertheless, the history of each of the main divisions of the fishes is very defective at many points, the forces of destruction having completely wiped out both the fossil-bearing beds and their contained fossils. The diagram in this case indicates only a few of the better known species of fossil fishes. Each group is derived from a central or generalized type. This, then, gives rise to many peculiar specialized side lines which sooner or later become extinct. Meanwhile, the central stock gradually progresses to the next higher grade.

OSTRACODERMS

(The Oldest Fossil Fishes)

[Cases 1 and 3]

Near Canyon City, Colorado, are found red sandstones of the Ordovician period containing small fragments of the most ancient and most primitive of all known fossil fishes. Better preserved specimens of this class occur in the mudstones of the succeeding Silurian period, in Scotland, Norway and New York State. It is estimated that the oldest of these specimens lived about four hundred million years ago. They belong to a large class of extinct, fish-like animals called Ostracoderms.

These fossils are of great interest because they illustrate the 'basic patents' of the vertebrate type of animal. That is, even at that remote period, they already had a fish-like body which moved by lateral undulations caused by the zig-zag muscle segments arranged along the sides of the body; the head comprised three pair of capsules for the nostrils, eyes, and internal ears respectively; behind the mouth was a cavity for

the gills, and presumably the back was stiffened by a simple axial rod or notochord—the forerunner of the complex backbone of vertebrates.

In some Ostracoderm fossils, the fine silt on which the animal died finally penetrated into the blood vessels along the bony channels of its main nerves and into the interior of the brain chamber. Thus, after the silt turned to stone, a natural cast of the brain and of the cranial nerves and blood vessels was left. These casts have been intensively studied by the Swedish palæontologist, Dr. Erik A. Stensiö. He has thus been enabled to compare much of the internal anatomy of these Silurian Ostracoderms with that of the lowest existing fishes, especially the lampreys and hag fishes, which are the nearest living relatives of the Ostracoderms.

The Anaspida. The Ostracoderms differed widely among themselves in external body form and in other details. In the primitive Anaspida, the body was fish-like, the head not enclosed in a single shield, and the eyes were on the side of the head.

The Cephalaspida. In this group, the head and branchial chamber together were enclosed in a large, more or less semicircular bony shield. This shield was produced by the ossification of the many-layered skin covering the forepart of the body. The eyes were on the top of the head.

The Pteraspida. The shield of the Pteraspida was formed without true bone cells. The small eyes were at the sides of the head. In some of these forms, the fine ridges on the surface of the shield in the fossil condition refract the light and give rise to a pearly lustre, hence the name "Ostracoderm," meaning 'shell-skin,' originally applied to members of the Pteraspid group only, and afterward expanded to include the entire class.

THE CYCLIAE

[Case 3]

This is a special group of early chordates, of unknown kinship. The representative is *Palæospondylus*, the "fossil lamprey-eel" much discussed in the literature of fossil fishes. It is characterized by well-marked vertebræ, a prominent head terminating in barbel-like processes, and a paddle-shaped (diphycercal) tail. It was found in the Middle Devonian of Scotland. Recent studies by Professor Graham Kerr of Glasgow and one of his students indicate that "*Palæospondylus*" is a larval lung-fish, the adults of which are found in formations of equivalent age.

ARTHRODIRA

[Cases 2 and 3]

Evolution of the Arthrodira [Case 2]: This exhibit illustrates the evolution of the Arthrodira, or Joint-Necked Fishes, as shown by changes in the size and structure of the head.

The Arthrodira were fish-like animals whose head, shoulders and abdomen were armored with plates of bone; their mouth was provided with powerful "teeth" or cutting plates. They ranged from a few inches to twenty feet in length and lived abundantly in the seas and rivers of the Devonian, becoming extinct during the beginning of the Coal Period (Carboniferous).

The earliest and most primitive type was the small *Phlyctænaspis*, ten or fifteen inches in length, represented both in Europe and America (Old Red Sandstone, Scotland; Lower Devonian, Canada). From a type like this, all other Arthrodira were descended. Among these we note: *Homosteus*, a large form found in the Old Red Sandstone of Scotland; *Coccosteus*, a small fish (one or two feet), most abundant in species of all earlier forms and surviving to the close of the Devonian; *Dinichthys* and *Titanichthys*, Coccosteus-like forms found in the Upper Devonian shales near Cleveland, Ohio, including examples twenty feet in length, the largest of this group.

Titanichthys: On the wall is mounted the head and front portion of the body of the giant Arthrodire, *Titanichthys clarkii* Newberry. The complete animal was probably fifteen to twenty feet in length. It came from the Cleveland shale.

Dinichthys: Below Titanichthys, in the cases between cases 2 and 3, are shown restorations of the head and front portion of the body of one of the larger arthrodires, *Dinichthys terrelli* Newberry. The pieces were found in the Cleveland shale of the Upper Devonian. The entire animal must have measured about fifteen feet in length. These two restorations have been followed, in 1930–31, by the latest restoration, made by Dr. Anatol Heintz of Oslo. A metal model showing roughly the arrangement of the armor plates of the head and thorax in this new restoration is to be seen in the case with the mounted head. This model illustrates the unique jaw mechanism of these fishes who opened their jaws by throwing the head back and drawing down the lower jaw. Four pair of muscles, worked respectively to lift the head roof, to move the head roof downward, to move the lower jaw upward, and to move the lower jaw downward. That is, the first and fourth pair operated to open the mouth and the second and third pair to shut it. This unusual mouth mechanism has never before been observed in any fossil or living animals.

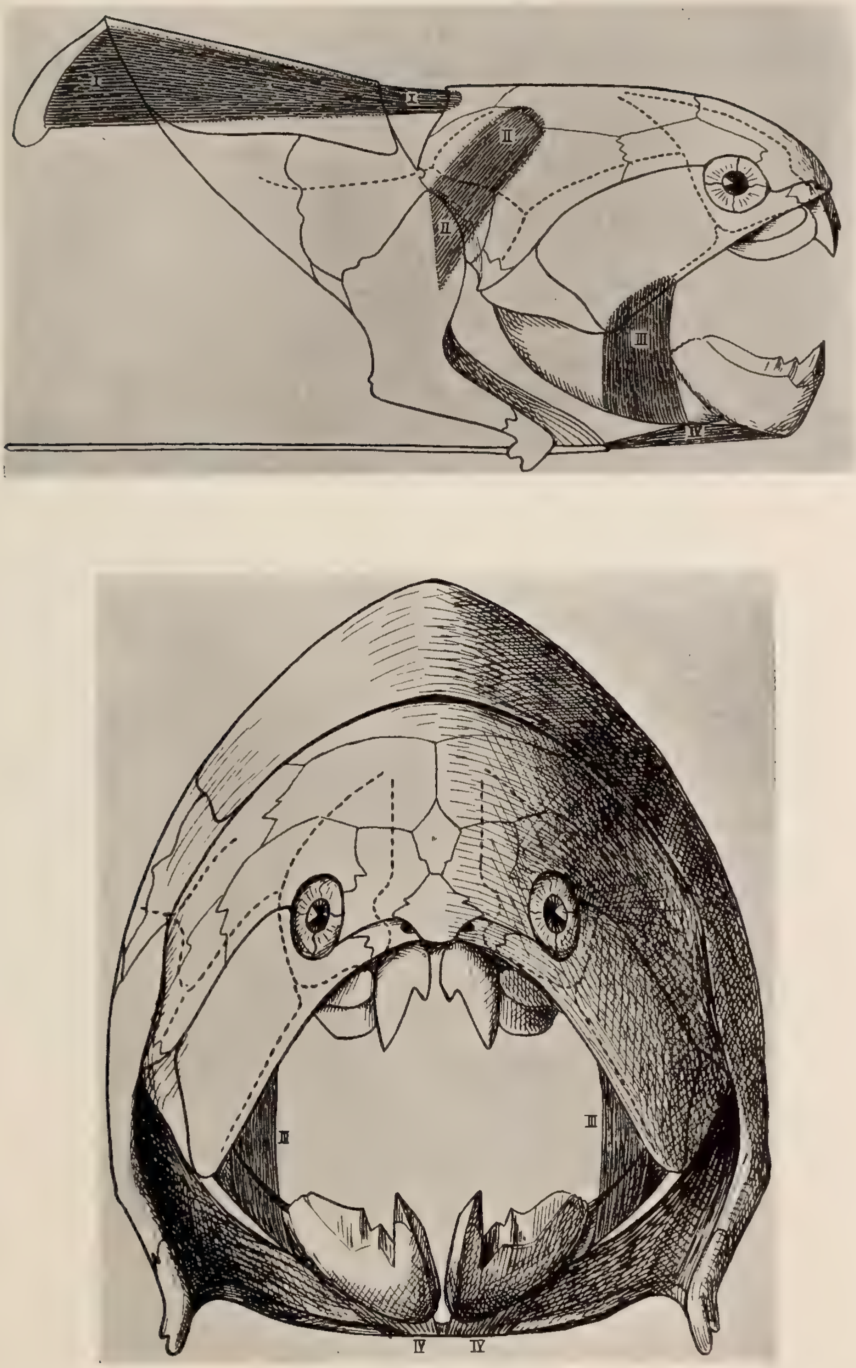

Fig. 16. Restoration of *Dinichthys*. Front and Side Views. By Anatol Heintz.

SHARKS

[Cases 3, 4, 5]

Sharks were among the first vertebrates to appear and have survived throughout all later geologic ages.

Giant Fossil Shark, *Carcharodon megalodon.* [Above entrance to exhibit]: About the time when the glaciers covered the northern part of North America, the seas were inhabited by gigantic sharks. The actual teeth of one of these monsters are shown above the entrance to the alcove. They are from the Tertiary of North Carolina. Their average height is $4\frac{1}{4}$ inches. They have been set in jaws modelled after those of the Man-Eater Shark, which is the nearest relative of the giant extinct species (*Carcharodon carcharias*). The estimated length of this fish in life is 46 feet. A scale drawing below the jaws shows its size as compared with that of the Man-Eater and that of the average man.

The Fin-Fold Shark, *Cladoselache.* [Case 4]: *Cladoselache* is one of the most primitive known types of shark. It lived in the sea during the Devonian. It was characterized by notochordal skeleton, fin-fold type of fins (embryonic fold of skin in which fin rays are developed), and eyes protected by many enlarged shagreen scales. The specimens in this case are from the Upper Devonian of Ohio. In some of the specimens the myotomes, or muscle segments, on the side of the body are preserved.

Pleuracanthidæ. [Case 3]: These are extinct primitive sharks. Their characters include a notochordal backbone, a strong spine at the back of the head, peculiar forked teeth and paddle-shaped pectoral and ventral fins. They have been found from the Carboniferous and Permian of Europe and North America.

Acanthodia. [Case 3]: The leading characteristics of this order of primitive sharks are shagreen close set and scale-like, each web-like fin supported by a spine, eye protected by a ring of bony plates, backbone cartilaginous (notochordal). They appeared in the Silurian and became extinct in the Permian.

Edestidæ. [Case 5]: These are extinct sharks whose nearest living relative is probably the Port Jackson Shark (*Heterodontus*). Of *Edestus*, the only structures preserved have long been regarded as spirals of teeth which projected in front of the mouth. They have been found in the Carboniferous and Permian of Europe and North America. In most sharks the most used teeth come to lie in the front line and eventually get broken off. In *Edestus*, however, the teeth of the symphyseal region of the lower jaw had such long stout "roots" that they could not break off but gradually grew outward into a tightly wound spiral in which the older and smaller teeth are nearer the center.

Fig. 17. Jaws of *Carcharodon megalodon*.

Skates and Rays. [Case 5]: Skates and rays are characterized by a cartilaginous skeleton; the skin is often studded with small tubercle-shaped scales; the teeth are flattened, often fused into pavement-like crushing plates; the gills open in separate slits on the under side of the neck. They were dominant in the Carboniferous and are greatly reduced at the present time. The early forms show many curious specializations in fin-spines and teeth, some of the latter pavement or plate-like.

ICHTHYODORULITES

[Case 5]

Ichthyodorulites are spines and spine-like structures of fossil fishes, many of which cannot as yet be associated with any particular kinds of fishes.

CHIMAEROIDS

(Silver Sharks)

[Case 6]

Chimæroids appeared in early geologic times and were most numerous and diversified during the Cretaceous. They form a small group of shark-like fishes whose existing forms with few exceptions inhabit the deep sea. Some extinct species grew to a length of over fifteen feet. Complete fossil Chimæroids are rare. They are mainly known from detached plates and spines. The living genera representing this group are also shown in this case.

This group is interesting to zoologists as survivors of an ancient stock more closely akin to primitive sharks than to any other fishes. In general they retain shark-like features, but in highly modified form. Their head is typically rat-shaped; their body tapering, with a wisp-like tail and large pectoral fins which are the main organs of swimming. The numerous scales of the shark have in large measure disappeared; the many small teeth are represented usually in three pair of dental plates; the many small valves of the base of the main artery become fewer and larger; the intestinal valve is present, not in many low ridges, but in a few ridges of great width, and the upper jaw, instead of being separate from the skull, as in sharks, is fused with it. The skeleton is cartilaginous and the dorsal spines strong.

Ptyctodonts: These fishes shown at the bottom of Case 6 probably belong to the group of Arthrodira, but by some are regarded as Chimæroids. They have been extinct since the Devonian and are known only from dental plates.

DIPNOANS

[Case 7]

These fishes are provided with a lung as well as with gills. They breathe through nostrils; have three pair of dental plates, and paddle-like paired limbs. At present they are represented by but a few species (*see* Hall of Fishes, Case 1), two of which, *Protopterus* and *Neoceratodus*, the African and Australian Lungfishes, are shown here.

The lungfishes, are, in many regards, like Salamanders. They appeared in the early Devonian and attained their greatest development at the close of the Palæozoic. Complete fossil specimens are rare. In early periods of the world's history the Dipnoans were a large and important group, abounding in nearly all fresh water. At present they are represented only by three genera, *Protopterus*, living in the rivers of Africa, *Lepidosiren* in South America, and *Neoceratodus* in Australia.

The structures which distinguish them are a lung, which may be single or double-lobed and which enables the fish to withstand the long rainless season when the rivers in which it lives become dry; teeth which are crushing or cutting plates, each with ridges extending crosswise over its surface, and the paired fins of the kind known as "archipterygia," *i.e.*, with an internal structure consisting of a jointed rod of cartilage having similar or smaller rods branching from it on either side.

The most ancient fossil lungfish is *Dipterus* which lived in the Devonian. It is well known by fossil remains from the Old Red Sand stone of Scotland. It had two separate dorsal fins and its head was covered with numerous small, enamel-coated bones.

It gave rise to *Phaneropleuron* which resembled it in the main, except that it was more slender and the two dorsal fins were united into a single long fin. The family to which *Phaneropleuron* belongs gave rise to two types of lungfishes, one a rather stout form, *Scaumenacia;* the other a more slender fish, *Uronemus.* These two types became in time more and more differentiated, gradually leading up to the families of lungfishes existing at the present time, the one including the Triassic *Ceratodus* and *Neoceratodus* of Australia; the other including the slender, eel-like *Protopterus* of Africa, and *Lepidosiren* of South America.

CROSSOPTERYGII

(Lobe-fins)

[Case 7]

The oldest of this group, from the Old Red Sandstone of Europe were long-bodied, pipe-like fishes with voracious mouths. Their pectoral and pelvic fins however were lobate or fringe-finned, that is with a more or less elongate bony and fleshy core surrounded on the front and

rear borders by long, fringing bony and dermal rays. The shorter lobe-like fins resembled the paired limbs of amphibians in having only a single bone, representing the humerus or the femur respectively at the proximal end of each paddle or limb. These forms (Rhipidistia) also approached the amphibians in skull structure and are believed to have stood close to the ancestral line of the latter. The Rhipidists have two dorsal fins and a peculiar type of tail. Among modern fishes two genera, the *Polypterus* and *Erpetoichthys* of Africa were formerly believed to be the direct descendants of the Devonian Crossopterygians, but Professor E. S. Goodrich has adduced evidence for his conclusion that they differ from the latter in many important structural features and that they may rather have been derived from ancient ganoids of the palæoniscoid type.

One branch of the Rhipidists gave rise to the strange Cœlacanths which lasted from Devonian to Cretaceous times.

GANOIDS

[Cases 8, 9, 12]

The Ganoids comprise an extensive group of fishes whose survivors include the Sturgeon, Garpike and Bowfin. The fossil members of this group were numerous during the late Palæozoic and early Mesozoic. They have prominent enamelled and bony scales and in many structural features are intermediate between Sharks and Teleosts. The specimens in these cases are mainly from the celebrated lithographic stone in Solenhofen, Bavaria. (Jurassic).

Pycnodonts. [Case 8]: The Pycnodonts (*pycnos*-crowded; *odous*—teeth) are extinct Ganoids with deep compressed body, persistent notochord, and numerous small grinding teeth. They were abundant and widely distributed during the Mesozoic era, but gradually became extinct, disappearing in the early Tertiary. Some specimens reached a length of three feet. Other typical extinct Ganoid fishes are shown in Case 9.

The Saw-finned Fish, *Protosphyræna nitida* Cope. [Case 12]: Among the strange fishes that swarmed in the ancient seas of Kansas, none are more noteworthy than the Amioid fish, *Protosphyræna*. Its bony snout was prolonged like that of a Gar; there were two tusk-like teeth in the upper jaw and very sharp teeth in the lower jaw like those of a living Barracuda. The front edge of the enormous pectoral fins was serrated, and it is supposed that the fish used these in attacking its enemies. On the left side of this case is a sketch of the skeleton of this fish; below it a sketch of the skull, and to one side a reconstruction made from the actual parts shown on the plaque with it. Across the bottom of the case stretch the huge, saw-edged pectoral fins.

THE FOSSIL AQUARIUM

The aquarium at the back of the exhibit alcove is a restoration of early fossil fishes from the Old Red Sandstone of Cromarty, Scotland. This group represents fossil fishes which flourished in the ages preceding the appearance of land-living animals such as frogs, reptiles, and mammals. The aquarium is designed as an aid in interpreting the fossils in adjoining cases, and it probably gives the more accurate picture since all the fishes shown were found in a single locality and in a single layer of Old Red Sandstone (Lower Devonian). In their coloring, they have been made to correspond with their nearest living relatives.

The present models show several kinds of sharks, a lungfish, two lobe-finned ganoids, and the earliest form of ganoid, *Cheirolepis*. In addition, there appear two fishes whose race is extinct, and whose relationships are obscure. These are the Placoderms, *Coccosteus* and *Pterichthys*. The habitat of these fishes appears to have been estuarine, fresh water, or brackish. The plants represented are from the same age and two of them from the same locality. The background was made by Charles R. Knight under the direction of Bashford Dean, in 1909.

TELEOSTS

(Bony fishes)

[Case 10]

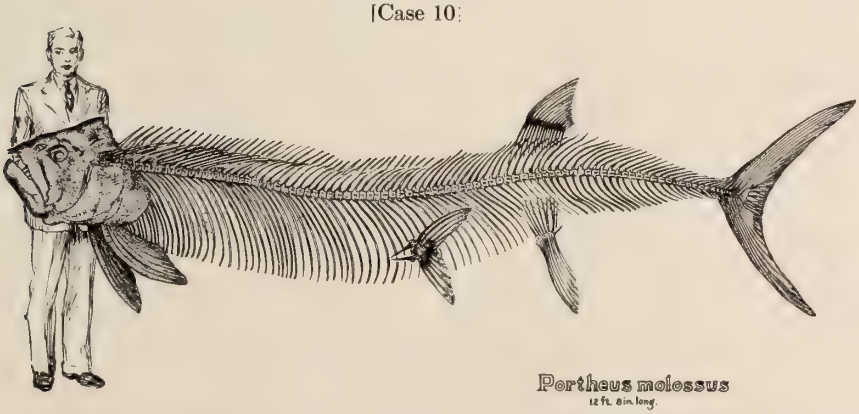

Fig. 18. Portheus, the Giant Bulldog Fish. Drawn by Louise Nash from a photograph of a specimen 12 feet 8 inches long, discovered by George F. Sternberg in the Kansas Chalk (Cretaceous).

To this group belong the majority of food and game fishes of the world—the Bass, Carp, Cod, Eel, Herring, etc. They are the dominant type of fishes at the present time. They are descended from and have supplanted the Ganoids. Many of their forms, including several orders, appeared during the Chalk Period,—the earliest being the Herrings

(Clupeoids) and the Ten Pounders (Elopidæ). An interesting series of transition stages of connecting links can be arranged leading by almost imperceptible degrees from Ganoids to Teleosts.

Structure: The Teleosts are exceedingly diverse in form, size, coloring and anatomical structure, having become adapted to the most varied conditions in seas and lakes and rivers. In size they range from the half-inch *Mistichthys luzonensis* of the Philippines—the smallest vertebrate known, to the gigantic Arapaima of the Amazon, which attains a length of over fifteen feet.

In typical Teleosts, the skeleton is bony or calcified; the fins light, flexible, and provided with complex muscles which insure rapid and diversified movement. The body is covered with thin, flexible, overlapping scales; the brain and sense organs are well developed, especially for sight and hearing.

Fossil localities: Fossil Teleosts are widely distributed. Most of those in this case are from the Green River shales of Wyoming. This geological formation consists of soft, buff-colored shales which appear to have been deposited in an estuary, or in a landlocked bay during the Middle Eocene. The fishes found in these shales are of great variety and beautifully preserved. These formed part of the collection brought together by the distinguished palæontologist, Professor E. D. Cope; the remaining specimens are from various localities and geological ages, as indicated on the labels. Among them are examples of the earliest Teleosts from the Cretaceous of Mt. Lebanon, Syria, also fossils from the Eocene of Monte Bolca, near Verona, Italy.

The Giant Bulldog Fish, *Portheus molossus* Cope. [Above back center of alcove, also Case 12]: This gigantic fossil fish occurs in the Cretaceous of Kansas. Its skull is shown in Case 12, and below it a key to the parts, also a restoration sketch to scale from a photograph of a specimen 12 feet 8 inches long. The specimen on the wall at the back of the alcove measures 15 feet 8 inches in length. The *Portheus* is remotely related to the existing Tarpon, its nearest living relative is the tiny *Chirocentrus dorab* of the Indian Ocean.

For a full description of this fish, *see* Bulletin American Museum of Natural History, 1904, volume 20, article by Henry Fairfield Osborn.

Recommended books for reference:

JORDAN, D. S. "Fishes." D. Appleton, New York, 1925.

NORMAN, J. R. "A History of Fishes." London, 1931.

NICHOLS, J. T., and C. M., BREDER, JR. "The Marine Fishes of New York and Southern New England." Zoologica, 1927, IX, No. 1.

BREDER, C. M., JR. "Field Book of Marine Fishes of the Atlantic Coast." G. P. Putnam, New York, 1929.

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Explanation of abbreviations used below: ew=east wall, Hall of Fishes; F=Fossil Fish Alcove, fourth floor; ff=Flying Fish Case, east wall, Hall of Fishes; p=paintings; V=Vanderbilt collection of paintings, Hall of Fishes; ww=west wall, Hall of Fishes.

Building the Museum Group

BY ALBERT E. BUTLER

Associate Chief, Department of Preparation and Exhibition

GUIDE LEAFLET SERIES, No. 82

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BUILDING THE MUSEUM GROUP

By Albert E. Butler

Associate Chief, Department of Preparation and Exhibition,
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The Habitat Group, which first made its appearance less than forty years ago, has, in the past twenty years, become a recognized factor in arousing the public interest in Museums. Even the smallest museum has adopted this method of displaying specimens, and the frequent calls from these, as well as from individuals, for information on the procedure of Group building has led the writer to prepare this pamphlet. The information presented herein, while brief, is sufficiently broad to give the uninitiated or the comparatively new worker a basis upon which to proceed. It is the author's desire to pass on the results of a long and varied experience in this field, giving such information as has been found to produce excellent results with economy and simplicity.

A successful Group requires the consideration and coöperation of the Curator, the Artist, the Taxidermist and the Accessory-man. This insures a plan which will not only be comprehensive and accurate, but will bring the utmost in interest to the museum visitor. This paper concerns chiefly the Accessory-man's work, which is the building and housing of the setting.

The successful worker in this field must possess ability to model, draw and color, and, in addition, have some knowledge of Botany and a mechanical sense. The plant life and other accessories should convey the same degree of accuracy and beauty as the subject of the Group, and this is possible only when the worker possesses all of the qualifications named.

I. Perhaps the simplest task in the accessory field is the reproducing of foliage. But even this, at times, may present difficulties.

a. In reproducing a simple leaf, such as an apple leaf, a plaster mold is first made. For this purpose a fresh leaf, or one preserved in its fresh form, is posed face up on a bed of soft water clay, which can be molded to support the contour and undulations without pressing on the surface of the leaf and thereby destroying its detail. When satisfactorily posed, after cleaning the leaf surface with a soft brush and water, a clay dam is built around the leaf, leaving a margin of about three-quarters of an inch. Plaster of Paris, mixed to a creamy consistency, is poured over the surface to a depth of about one inch. Spraying the surface lightly with water before pouring plaster will prevent bubbles; or brushing on the first coat of plaster will bring the same result. When the plaster is "set," lift it from the clay and remove the leaf; ream out two or three

"keys" on the margin of the mold and, after soaking thoroughly in water, brush the whole surface with heavy soap water, a soft mixture of stearine and kerosene or with lard oil to prevent sticking. Build a clay dam about this and again flow with an inch of plaster. When this is set, you will have a two-piece mold with surfaces in perfect contact. Where the under side of a leaf will show in the Group, the leaf should be left on the first mold and the second layer of plaster flowed over this. However, the leaf is removed preferably where at all possible, because a thinner wax impression will result from molds with surfaces in perfect contact.

Molds mounted in a clamp. Materials used and successive stages in leaf making.

It will be necessary to gouge out the plaster where the midrib occurs on the half representing the back of the leaf, and in some cases the more prominent lateral ribs should be accentuated by the same means.

Where many leaves are to be made, the molds should be mounted in hinged clamps in perfect alignment. This will eliminate unnecessary wear and imperfect impressions. A plaster mold should stand about fifty impressions. Where a great number of leaves are to be made, it will be found more satisfactory to use type-metal molds. (See Directions for Making Metal Molds.) *b.* Wire is used to support the leaf, and should be cut into lengths about an inch longer than the leaf from tip to end of

petiole, and of sufficient size to support the leaf without sagging. The wires should be tapered by tying into bunches and dipping into nitric acid and draining alternately until the desired taper is obtained. Wash off the acid and rub with fine sandpaper to remove the rusty deposit. Wind each wire with a film of cotton, and, if the mold is undulated, bend to the contour of the midrib before beginning to press.

c. Jeweler's, or Johnson's, absorbent cotton forms the base for the leaf, and should be torn into thin slabs, each piece just large enough to cover well the leaf surface.

d. Beeswax, never paraffin, is used to give the leaf body and detail, and should be liquified by heating in a double-boiler.

When the molds are soaked in water as hot as the hand can stand, the preparation for pressing is now complete.

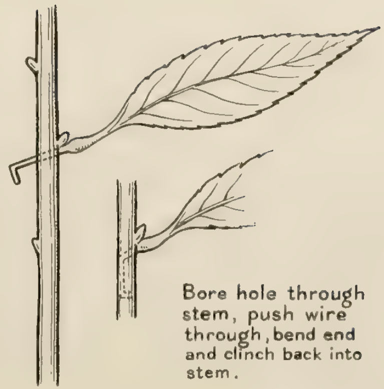
e. A cotton-wound wire is placed in the groove which represents the midrib, a sheet of cotton placed over this and a sufficient amount of the hot wax poured over this to insure the leaf surface being wholly covered. The clamp must be closed as speedily as possible after pouring the wax, as this alone is the secret of making thin leaves. Very little pressure is required. If two or three clamps are manipulated in series, the first impression will have cooled properly for removing by the time the second or third is poured. Moisten the mold surface after each impression.

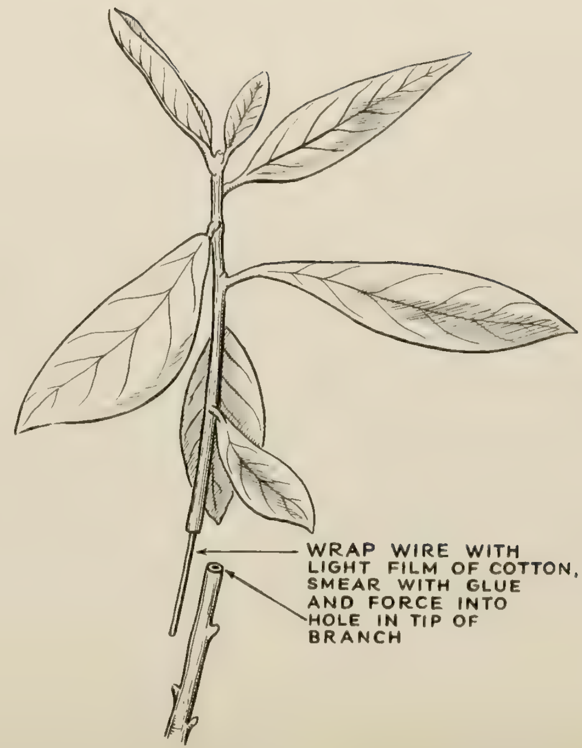
The hot wax may be given a body color by dissolving oil color in it. Care should be used not to overload with the paint, which may cause the wax to emulsify and make it unfit for use. Use Flake or Permalba white; never zinc. Wax, once melted, should be kept on a very low fire, with water barely simmering. This gives the proper temperature for pressing.

Experience and a careful study of results will soon show the proper amount of cotton and wax required for perfect results. A good general rule is, "Use a maximum of cotton and a minimum of wax."

f. The excess wax is trimmed from the margin of the leaf by using slightly warmed scissors. If the margin is smooth, then the trimming is accomplished by a sliding motion of the scissors. If serrate, the result is effected by a choppy motion. There is a knack in this operation which will be acquired only through considerable practice. Every Accessory-worker has, I believe, at some time attempted to simplify the serrating operation by inventing a special tool, but its very mechanical nature defeats the object, which is to gain a natural finish. The amount of finishing required on a tool-trimmed leaf more than offsets any possible saving of time in trimming.

The edges of the finished leaves should be thinned sufficiently to give a natural appearance, and this is best done by pinching the barest margin between the thumb and fore-finger. A sliding motion of the thumb on the





METHODS FOR SECURING LEAVES OR BRANCH TIPS TO REAL BRANCH

back of the leaf and the natural warmth of the hand accomplishes the result.

g. In most cases, leaves are built into clusters after the character of the plant, and these "tips" secured to the real branch. If the plant be a small succulent one, then the whole assembly is built onto a wire stalk, which is modeled and bent, as the assembly progresses, to give the character of the plant.

Too much stress cannot be given the importance of lightness all the way through. Keep all materials to a minimum, so that the finished branch will rigidly support the weight placed upon it.

II. Materials other than wax may be used in leaf making, such as celluloid and paper. Celluloid possesses advantages in special instances, and there are two methods in common use. The first requires a plaster mold of the upper surface of the leaf and sheet celluloid of a thickness suitable to the subject to be reproduced. The celluloid is dipped into diluted acetone, or other solvent, then dipped into water and applied to the water-soaked mold surface with a backing of water clay to hold it in contact until "set." When removed, a tapered wire is dipped into celluloid or acetone solution, and applied to the back along the midrib.

The second method requires metal molds, set in clamps. (See Metal Molds.) A piece of sheet celluloid placed between the molds and clamped tightly under very hot water will take the impression. For making petals of flowers such as the Dogwood or Magnolia, this process has a distinct advantage in that it has the required rigidity without the use of wire. However, in leaf work, neither process is practical where many leaves are to be made because of the inflexibility of the material. To obtain a desirable variation of form and size, many molds would be required, and there is a stiffness in the finished work which cannot be entirely lost. Wax, on the other hand, requires few molds because each impression may be varied in form, and slightly in size, without losing the character of the leaf. Further, wax permits of alteration even after assembling.

III. The use of paper in making leaves is confined to occasions where an effect is best obtained by its use and the position of the plant in the Group permits it. As an example, a banana plant well back in the Group space where small imperfections would not be seen might be made by using a plaster mold of the surface of the leaf and applying wet paper, after the manner of making paper forms of dolls, globes, etc. Apply each successive layer with a paste made of flour and a little liquid Plaster of Paris added before applying. This gives a stiffness and "set" in a short time. A midrib of split bamboo or flattened wire should be placed in position between the layers during the process of building. When dry, this form

may be given a coat of varnish and color, producing a very satisfactory effect with little labor. Another paper method may be illustrated in the making of a pinnate palm leaf. Here the leaf form is drawn out on a sheet of cardboard of suitable thickness and quality. The cutout is best made with a razor blade, and when a tapered piece of split bamboo is applied along the midrib to near the tip and all secured with Du Pont's cement, the result is a leaf with a droop very like that of a palm. The detail may be suggested by scratching the upper surface with sandpaper. Similarly, bamboo lends itself to this method, using a tough paper in place of the cardboard. The finished cutouts are pasted to the real bamboo branches. In either case, the cutouts should be coated with liquid celluloid. Paper is also an excellent medium for reproduciug long lanceolate leaves, such as occur on reeds or small cat-tails. For long cat-tail leaves and similar subjects, wood (straight grained pine or basswood) is very satisfactory. It should be cut into very thin strips and shaped to desired form. Sandpaper will produce the detail.

The methods used in making artificial flowers and foliage for commercial use are adaptable in many cases to the requirements of Group accessories, particularly where a large number of impressions are to be made. As has been stated, nothing is of greater importance than choice of just the proper material and method for the subject to be reproduced, and paper or cloth will often produce more satisfactory results than either wax or celluloid.

a. The equipment required for the commercial method may be obtained from any artificial Flower Tool Company, and is as follows: Cutting dies, veining dies, cutting block, stamping press and mallet. The last three are permanent equipment, and will last for many years. The dies vary in cost, but will always be found to more than offset this cost wherever the impressions to be made run well into the hundreds. All prepared cloths for this work are starched, and it will be found necessary to dip the material in hot wax to give it a thin protective coating, which will prevent warping. For very small leaves or petals no waxing is necessary. Paper should be sealed from atmospheric changes by coating on either side with liquid cellulose. If a waxy texture is desired, the paper may also be given a coat of wax. Experience in this field to date points to paper as the preferred medium, because of its lower cost and the variety of textures and quality available. Further, it will stand up better than cloth.

IV. Objects, such as fruits, should be cast while fresh since these will a not preserve satisfactorily in solution. It is usually necessary to make "piece mold" of such things. An apple, for instance, would require a mold of two pieces, or perhaps three. A more irregular object might

require several pieces in order to insure the mold releasing without breaking because of undercuts. Agar is sometimes used for casting objects where a piece mold is required. Hot wax may be used in an agar mold, and for the novice the process is perhaps simpler. (See Agar Formula.)

V. Petals of flowers are most often made in wax, using the same process as in leaf-making, except that wire is seldom used in petals. In other words, only such flower petals as will reproduce in wax without wire support are made by that method.

Piece mold showing how an apple is cast.

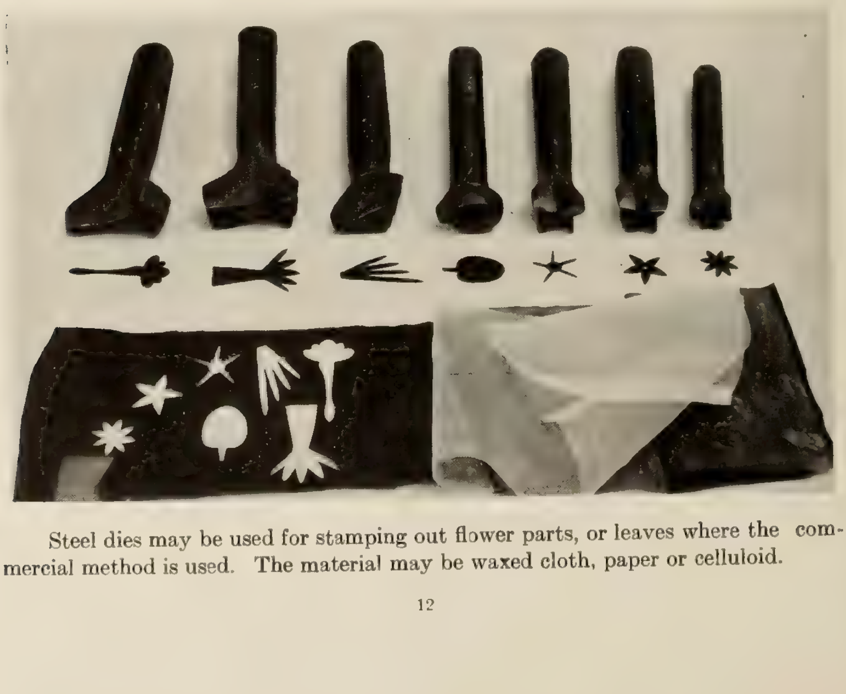
a. A flower of the dandelion or wild aster type may be closely imitated by using mousseline dipped in wax of the color desired. This is cut into strips slightly wider than the length of the petals, and then cut fringe-like, with each segment the width and length of the petals. When this fringe is wound tightly about the tip of a wire, it resembles the composite structure of the flower.

b. Most small flowers are best reproduced by the use of wax-saturated cotton made in squeeze molds with flat contacting surfaces. This gives a tough, thin material, which will easily mold into shape in the palm of the hand with the aid of a tool. The petal forms should be cut to a carefully drawn pattern. A wooden tool, shaped for the particular job on hand, and kept moist, will be found most satisfactory for molding the wax petals.

c. The celluloid processes, already mentioned, cover all other petal reproduction. The fine, frost-like texture characteristic of some flowers is readily imitated by dipping the celluloid petals in hot wax.

Flowers made of sheet celluloid pressed in metal molds.

Flower made of cotton and wax in plaster molds; pistil of wax on tip of wire stem, with stamens of wax-tipped thread.



Steel dies may be used for stamping out flower parts, or leaves where the commercial method is used. The material may be waxed cloth, paper or celluloid.

d. The calyx may be cast in wax by the same process as that used in making leaves. Or, if many are to be made, the form may be stamped out of wax-saturated cotton or waxed mousseline with a steel die made to pattern. *e.* Stamens are commonly made by drawing thread through hot wax and, after cutting into proper lengths, dipping the tips into hot wax until a little ball, the size of the anther, appears. For more accurate work the stamens may be made in glass by drawing to proper thinness in a blow-flame and shaping the tip, while malleable, to form the anther. The pistil is usually modeled on the tip of a wire, which is to form the flower stem. The stamens and other parts are secured to this with wax applied with a heated metal tool.

f. Success in making artificial flowers comes rapidly with experience, for when one has learned how to handle wax, he quickly recognizes its possibilities and limitations and can readily judge which process is best suited to the subject at hand. Ability to judge the best medium for each problem is as important as ability to attain a technically satisfactory result.

VI. The finished coloring of both leaves and flowers is best done with an air brush. Where this is not available, the coloring may be applied with a brush by hand, or by spattering from a brush. The latter method may be developed to a remarkable degree of fineness. Coloring of the veins requires a fine line brush. It is often desirable to coat the wax with French varnish before coloring. This will prevent wax from absorbing the color.

The soft, downy hair sometimes found on leaves is represented by blowing fine cotton flock over the surface after applying a thin coat of varnish. Likewise, the hair on a leaf stem is very well imitated by either silk or cotton flock. These materials may be obtained in several degrees of fineness.

There are several ways in which a tree trunk may be represented in a Group. It is seldom practical to use the real tree. Wherever this is done, however, the wood should be thoroughly poisoned or otherwise treated to make sure the insect life in it has been destroyed.

VII. Wherever the bark can be readily removed, this is undoubtedly the most satisfactory for the purposes of reproduction. (See Photo Plate No. 5.) This should be poisoned by dipping in or painting with arsenic solution to prevent development of any insect life which may be in the bark. With the aid of good photographs of the original, the bark can be fitted to a wood frame with such accuracy as to make it undistinguishable from the original. Where it is impossible or impractical to take either the tree or its bark, then a complete set of photographs from all angles, together with a sample of the bark, will insure a faithfully reproduced

tree in the laboratory. For this method a wood frame, made slightly under the measurements of the tree, is covered with wire mesh, burlap and plaster. This is given a coat of shellac and the detail applied with slow-drying papier maché. (Formula—Dextrine Maché.)

VIII. Most grasses are easily preserved (See Formula for Glycerine and Formaline Solution) and in most cases, this is the best procedure. This, as well as other material preserved in this solution, loses its color and

Trees are reproduced by using original bark, wherever possible, as shown above, but more often must be entirely modeled in maché or plaster from photographs.

emerges darker. When all excess moisture is evaporated, the grass should be wiped carefully to remove dust, and a coat of oil color applied, preferably with an air brush. This first coat should be much lighter in tone than the final color, and contain some body white. When this is thoroughly dry, apply the finish coat with transparent, or nearly transparent, color. Oil paint is heavy, and should be used as sparingly as possible on delicate preserved grasses, or they will sag into unnatural position. In drying, it is good practice to hang the grass clumps upside

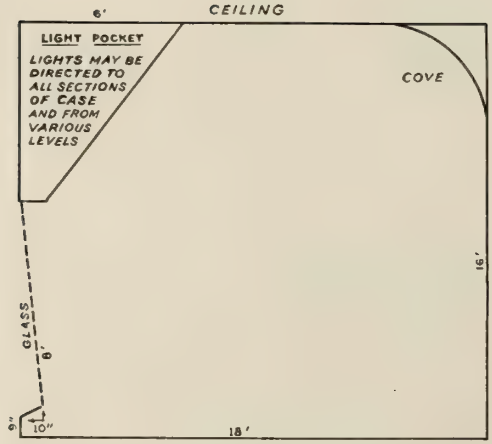
down. Sometimes it may be desirable to artificially produce grass. This is accomplished by cutting wax-dipped mousseline, or very thin celluloid, into grass-shaped strips and securing these to a wire. Fresh Spring grass will not preserve, and should be reproduced by the latter method.

Mosses preserve readily in the glycerine solution. This is done either by immersing the fresh moss for about twenty-four hours, or by spraying several times a day for a few days. Both mosses and grasses may be restored even after dried from age by first soaking in very warm water, and then immersing in solution for about a day. In fact, in most cases these things preserve better after having dried first. Mosses are colored after the manner of grasses, or by dusting on dry color.

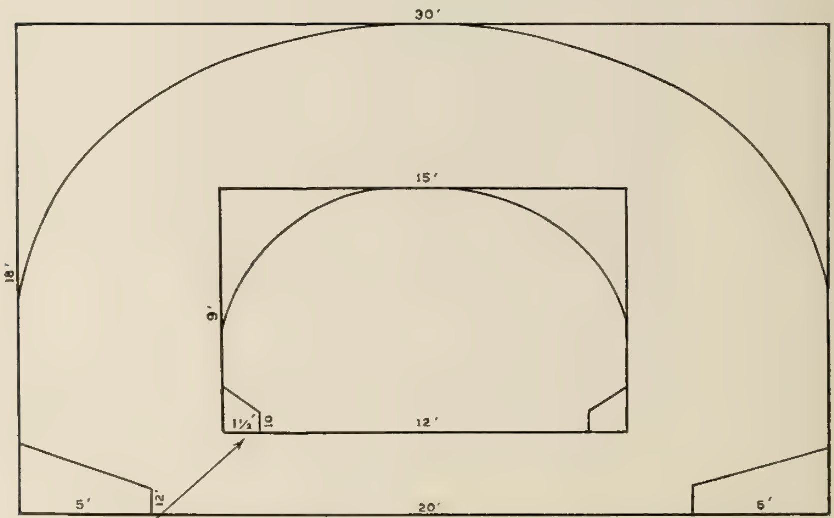
IX. Rocks of any appreciable size are never used in Groups. Either they are reproduced by making plaster molds from the original, or by carefully modeling after photographs. A combining of the two processes may be found most practicable where there is a great amount to be made. *a*. To make a plaster mold from a rock, the subject must first be well oiled, so that the plaster will readily release from it when set. *b*. If the work is to be done by modeling alone from photographs, then a form of wire mesh is molded after the contour of the rock, and this is covered with burlap dipped in plaster. The details of modeling and texture are added with plaster. *c*. A wet sponge, dipped in thin plaster, if skillfully handled, will give a rock texture of considerable variation. Other methods will suggest themselves to the resourceful worker. Ground cork mixed with the finishing plaster coat will be found useful in obtaining a coarse granite texture. Dry color is sometimes mixed with plaster to give a base color, but the author does not recommend its use. It is more satisfactory and much less expensive to paint the white plaster with Diamond Dyes, after it has set.

d. When the plaster is thoroughly dry, give it a light coat of shellac, and then paint with oil colors. Spattering the color from a brush is usually more effective than spraying, especially on granite or like rocks. The spattering adds to the effect of texture. Dry colors mixed with Dextrine Solution are ideal for coloring rockwork. Apply Dextrine size to plaster surface first.

e. A large section of rockwork may be reproduced to perfection by making piece molds of the original and setting these up in position and building into the mold a mixture of cement and dry color with fine ashes (1 cement to 4 ashes). When the plaster mold is chipped away, the result is a completely finished, colored rock. Cement has a natural texture similar to rock, as well as a gray base color, which is desirable.



CROSS SECTION OF 18'X 30' GROUP WITH 16' CEILING, LIGHT POCKET AND OPENING



CORNER SPACES MAY BE USED FOR LABELS, SMALLER GROUPS, MINIATURE GROUPS, OR ADDITIONAL LIGHTS IF DESIRED.

SHOWING WELL PROPORTIONED GROUP AREA, CURVE OF BACKGROUND AND OPENINGS IN GROUPS 18'X 30' AND 9'X 15'.

X. Dry leaves for the ground may be preserved by soaking in fairly hot water and then immersing in glycerine solution for a day. When thoroughly drained and excess moisture is evaporated, the leaves will be sufficiently flexible to stand handling without breaking.

XI. The curved panoramic background, which is now in universal use for museum Groups, may be adapted to almost any architectural condition with more or less success. *a*. However, for best results, any hall of Group exhibits should be laid out on paper to determine requirements in advance of the drawing of the architectural plans. It does not follow

Under structure for a background. Metal may be substituted for wood.

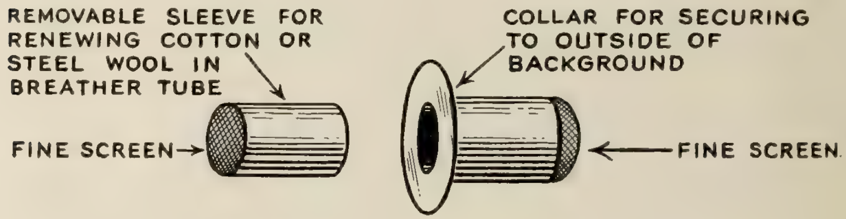
that an already existing Hall may not be suited to Group exhibits. Indeed, it may be admirably so. Much depends upon the size of the Groups desired. *b*. For instance, in a Hall of North American Mammals, where there must be shown buffalo, moose, elk and other large animals, the Group area should be from approximately 18×30 feet for the largest animals to perhaps 10×15 for the Virginia deer. Smaller animals would require a proportionately smaller area, always keeping the horizontal depth at about 60% of the width. Not less than a 16 foot ceiling can give a wholly satisfactory effect to a Group of 18×30 feet. Therefore,

even the smaller Groups in the same Hall will have an equal height, which is rather an advantage than otherwise.

c. The curve of the background should be continuous, but not a perfect arc. A sharp break in the shoulders of the curve should be avoided. In others words, do not make the form a horse-shoe. *d.* It will be found advantageous, though not absolutely necessary, to cove the background, not too sharply, slightly below the ceiling line, especially in open Groups where much of the sky shows. This will carry the eye beyond the frame as the Group is approached, and give a feeling of greater area.

e. Methods of constructing backgrounds for Groups are so variable that it seems advisable to give details only of those which are obviously practical from the point of view of durability and low cost.

Preferably the Group case should be fireproof. Therefore, wherever possible, the framework should be made of light metal, covered with



"BREATHER" TUBE

metal lath or galvanized wire mesh. Apply to this a hair and mortar mixture, just as for ordinary wall finish. When thoroughly dry, coat the back with asphaltum and the front with shellac. *f.* Apply the canvas to this surface with a mixture of spar varnish and white lead of thick creamy consistency. However, if wood is used for the framework, the back should be covered with sheet asbestos. The canvas covering may be omitted, in which case the mortar is given the usual plaster smooth coat. This, when dry, is coated with shellac, and this followed with two coats of white lead, the first brushed on, and the second stippled. This will give a canvas-like texture. In any case, the background form should be free floating; that is, not secured to either ceiling or floor. With such construction, no cracking should ever develop. *g.* The floor and ceiling lines should be well calked to insure against dust entering the Group.

h. A "breather-tube" installed near the base of the background will further insure against dust. Such a tube is made in two sections, so

that the cotton or steel wool filler, which is used in it to catch the dust, may be replaced from time to time. The tube forms a "point of least resistance," which takes care of contraction and expansion within the Group due to temperature changes, and thus prevents cracks which might otherwise develop.

XII. The opening in the case front varies with the size of the case, the size of the animals to be shown and the character of the exhibit. For entirely satisfactory results it is necessary to lay out on paper the whole hall plan. This insures symmetry of the architecture in the inner hall, and a favorable relation of the Groups, one to another. The 18×30 foot Moose Group mentioned should have an opening approximately 8 feet

Scale model of a hall. This layout assists materially in deciding best possible arrangement of groups.

high×20 feet long (here the great width influences the size of the opening because of the difficulty and hazard of handling large glasses), the top of the glass being about 9 feet and 3 inches from the floor. These dimensions may be shaded some to meet the requirements of the hall as a unit.

In the case of a Group of foxes, where the floor area might be approximately 6×10 feet, a better picture effect will result if the groundwork is raised to about 2 or 2½ feet from the floor. In this instance, the glass area would be 7 feet×6 feet 9 inches, if the top line were to be maintained to that of the Moose Group. These proportions obviously would be better if the top line could be dropped to 8 feet, giving a glass 7 feet×5 feet 9 inches. If the entire hall plan is laid out before proceeding with any one Group, the problems are known, and it will be possible

The above photographs show the miniature model and the finished group. While the original character of the model has been maintained certain changes were necessary to achieve the desired effect.

to keep a balance architecturally and at the same time display each Group to best advantage. To avoid reflections, it is desirable to install the glass on a slant, as shown in Cut No. 1.

XIII. Miniature group models are helpful in planning a Group if carefully worked out in scale. However, the usual procedure of modeling carefully the required animals to scale, and then sticking in anything to represent the trees, etc., without regard to scale, is misleading and a waste of time. A good Accessory-man will be able to portray character in a scale model of a tree or other accessory so that it will bear a proper relation to the animals. Leaves for trees in scale work are easily made by cutting the forms, many at a time, from a sheet of folded paper and the veining indicated by scoring with a tool over a blotter. These are readily attached to the minature tree branches by the use of Du Pont's cement. Branches of small shrubs may often be used to represent branches of scale trees. Smaller plants are readily mimicked by paper cut-outs secured to broom straws or any slender frond which answers to the scale and character required. Scale grass of various heights, in most cases, is best imitated by excelsior. It is obtainable in several degrees of fineness, and is easily manipulated to give grass character.

Galvanized sheet metal is ideal for backgrounds of miniature Groups, as it will readily bend to the required curve. The surface to be painted on should be washed with vinegar, and then coated with two or three coats of white lead, all coats stippled on, except the first.

A scale model, in which every part has been worked out in proper relation, will give all concerned some conception of the effect and character of the finished Group. However, one should keep in mind that in making the scale model he has himself remained full scale, and should therefore be prepared to make any deviation from the model that may seem advisable or necessary in the course of assembling the finished Group. In other words, be guided by the working out of the Group, rather than by the model.

XIV. The lighting of a Group is done mainly from the space directly above the window where an enclosure is built, for the purpose of excluding the heat of the lamps from the Group proper. A ventilator tube should be installed at either end for carrying off the heat. The enclosure will be as wide at the base as the opening of the Group will permit, and slant outward into the case as far as possible and yet not be seen from within two or three feet of the Group. Provision for reaching the lights for replacing must be made. Such a light pocket makes possible the lighting of the entire foreground, either directly or indirectly, as required. However, it is desirable at times to place lights in other parts of the case, but, if avoidable, none ever should be so placed as to make it necessary to

enter the case for replacement. For the average Group, a pleasing effect is obtainable from the latitude of the front light pocket, as outlined. Sunlit spots are very effectively simulated, either by the use of spot lights or reflected light from a mirror.

XV. A case front can be, and should be, constructed so that it is removable, for it will be found that the inner surface of the glass needs cleaning at last once a year. To go into the Group space for this cleaning will, in time, seriously damage the groundwork of the Group and whatever accessories are near the front. If the front is mounted on casters, and so designed that it can be readily detached, a wheeled truss, constructed so that it can be attached to the front, will make a complete unit which can be moved easily and with safety.

XVI. The base on which the groundwork of the Group is to be constructed is made according to the character of the setting, the size of the Group and the construction of the case front. Wherever possible, the Group front should be left entirely open, a dummy front being used during installation whenever necessary. This permits the building of the base in one piece. If the case front is installed, it becomes necessary to build the base in three sections, the centre section wedge-shaped, since it will be found desirable to remove the base frequently during assembly. Swivel roller-bearing casters should be installed on all base sections, to permit easy handling. The framework lumber should be proportionate to the load it is to carry. Frequent uprights are nailed to this, following the determined contour of the Group base. Iron wire mesh is nailed over the uprights, and this surface covered with burlap dipped in plaster. This should be made sufficiently strong to support one's weight. Reinforcing the underside will accomplish this. Or, where greater strength is required, sisal fibre may be substituted for the burlap. Where large rocks occur, these should be built as a part of the groundwork structure. Large trees and necessary anchorage for animals must be placed before laying the wire mesh. Usually, it is best to permanently place the animals before the accessories are installed. It is also best, in assembling, to place the material nearest to the background first, in order to enable the artist to connect his painting with the foreground without walking over any finished part. Naturally, if the case front has been left open, there will be no difficulty in joining, since the groundwork may be removed whenever necessary.

The surface of earth, twigs, dry leaves, etc., is the last operation in finishing any part of a Group. A mixture of cement and sifted ashes, about one to four, with dry color added if desired, is applied to the plaster surface, and the earth, etc. worked into this sufficiently to hold it in place and obtain a natural effect. Dry, preserved leaves may be scat-

The base for groundwork should be made strong and follow closely the finished contour. In this case the form was slatted to give the flowing form of drifted snow.

tered over this loosely; or, if necessary to secure them, dip into a diluted solution of glycerine and gelatine before applying. The solution should be of such consistency as to leave no gloss on the leaves when dry, yet retain sufficient adhesive quality to hold the leaves in place.

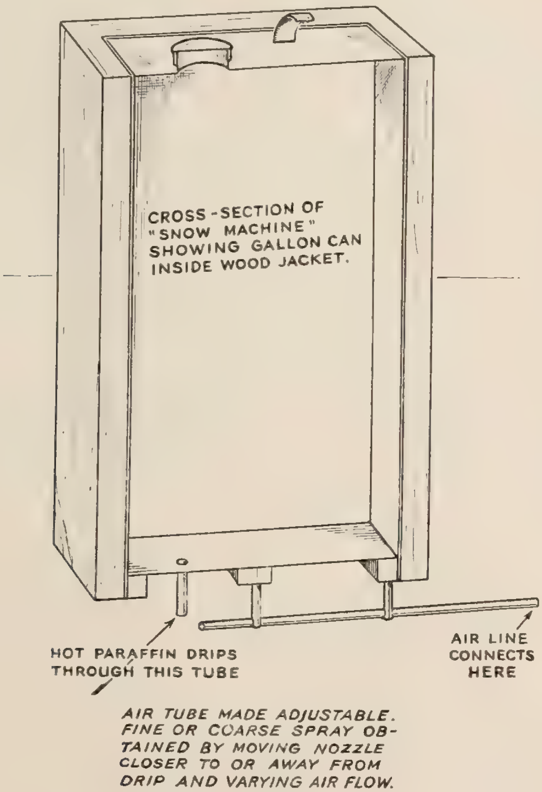
The "tieing-up" of the foreground to the background and the successful portrayal of the character of a setting are so greatly influenced by the placing of the horizon line in the painting, that it should be considered along with the business of building the foreground. It should be kept in mind that we are building dimensional "pictures." Size, character, dimensions and placement of Groups are all factors in determining the placing of the horizon. Let the requirements and specifications of the individual Group determine the most effective point for the horizon, and never be influenced by "actual eye level," a thing which cannot exist in a Group picture because of the great variation in height of the Museum visitors for whom the exhibits are produced.

In building a Group base where water is to be shown, the procedure is as follows: The under-water portion is worked out up to the water level, where a sheet of glass is installed. The shore-line above water is built separately from the main Group base, so that it may be removed as often as necessary in working out the under-water effect, including the installing of whatever forms are to appear as projecting from the pool. The glass usually requires some additional treatment. Painting or flowing the surface with celluloid (colored as desired) gives a watery texture. Or, the effect may be obtained as described in "Gelatin-Glycerine Formula." A slight clouding of the under-surface of the glass will produce a deceptive effect of depth, or of cloudy water.

Snow is best represented by spraying hot paraffin onto a white plaster base, which has been carefully modelled to the desired finished contour. Any coarse atomizing apparatus may be used for this. The plaster must be dry, and the first spray applied with the paraffin well heated and the spray nozzle fairly close to the surface. As the spray is thrown further, it will deposit in fine, snow-like particles. For coarser textures, use the paraffin less hot. Varying results may be obtained by regulating the heat of the liquid and the flow of air. The soft puffs of snow sometimes seen on branches may be reproduced by securing a fluffy bunch of cotton to the branch and spraying with paraffin. In small Groups, the paraffin may be spattered from a small hand scrub-brush to give the same effect as atomizing.

XVII. The equipment for collecting Group material should be carefully planned, and to do this it is essential to have as definite an idea of the Group plan as possible and a knowledge of the locality in which the collecting is to be done.

Excessive equipment is as annoysome in the field as a lack of it. Simple tools, such as saw, hammer, screw-driver, pliers, hand-ax, solder-iron and knife, should always be included. Ordinary materials which are commonly needed on any expedition are: plaster of Paris, plasticene, formaline, solder, solder-paste, burlap, cheese-cloth, twine (medium and heavy, with large spaying needle), water colors and brushes, stencil outfit and adhesive tape. The tanks for preserving leaf and other material

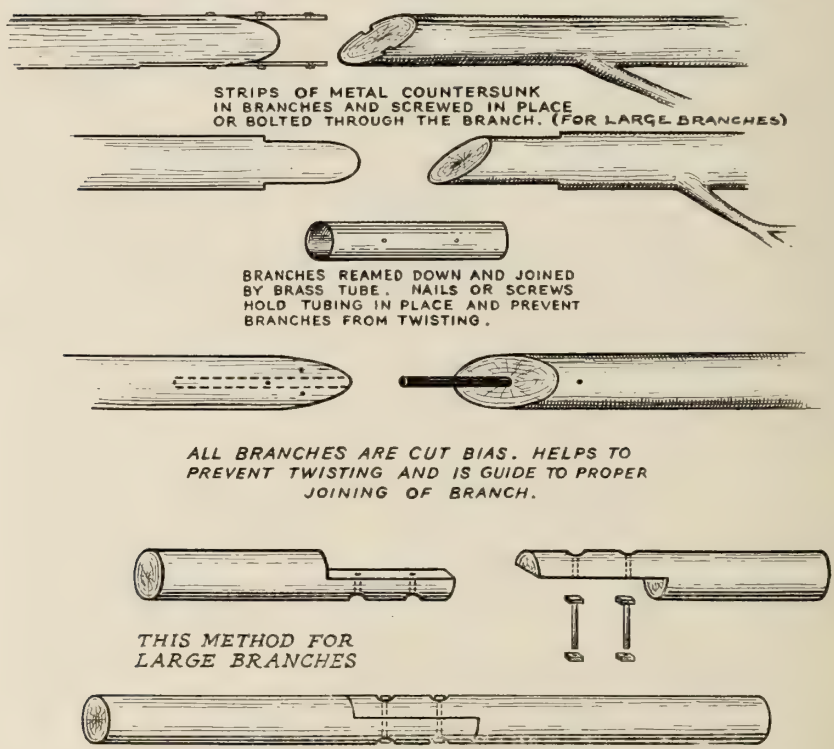


should be cylindrical. Material is more apt to jam in square tanks. Where more than one tank is required, the sizes may be graded so as to pack one inside the other. Much of the other equipment can be packed inside the innermost tank and in the corners of the box in which the tanks are packed. Thus, virtually the entire equipment may be taken into the field in one unit.

XVIII. The first work of an expedition is that of selecting the locality which is to form the basis for the Group. The plant life and other

accessories selected will be only such as are common to that particular locality. Those forms most typical and, at the same time, most practical for reproducing are chosen. Fresh leaves and flowers, together with small branches, or plants entire, are put into a solution of 3% formaline. Leaves carefully chosen for variety of character and size are stacked, card-like, and wrapped in cheese-cloth and dropped into the solution. All tender parts or plants should be wrapped in the cloth before placing

METHODS COMMONLY USED IN JOINING BRANCHES



in the tank. Short, brittle grasses require the same treatment. All this material, after remaining immersed for a few days, may safely be drained, leaving only a quart or two of solution in the tank. If the tank is well soldered, this will remain in good condition indefinitely, and the lightened tanks will transport more easily. As an additional precaution, plaster molds of leaves and petals are made in case anything should go wrong with the tank material. Water color notes should be made of all plants while fresh. Careful pattern drawings of flower petals and parts should be made.

Tree or shrub branches should be taken, as far as is practical, and cut suitably for packing, keeping always in mind that these are again to be joined in the laboratory. Long grass will ship in very good condition if strapped to a board or slab of bark for stiffener and wrapped snugly in burlap.

The necessary operations in taking records of rocks and trees have been covered in another section. Dry leaves and twigs should be taken from an area corresponding in size with the Group area. These will ship safely if wrapped in burlap and packed in a box. If the ground is more or less bare, a good amount of the surface silt should be taken—a sufficient amount to cover the floor of the Group. Always a goodly sample of the earth is taken; this will be ample for the worker to properly match at home for use in the Group. Too many notes and photographs cannot be taken.

Finally, all material should be inspected immediately upon arrival at destination. All dry material should be preserved or poisoned, and the material in tanks should be examined to make sure it is in good condition.

Agar Agar

XIX. To 6 oz. Agar add 1 qt. water. When thoroughly soaked, boil in double boiler and add 3 lbs. glycerine. Continue cooking until water is well evaporated. Add a few drops carbolic acid. Allow to stand until evaporation is complete. The resulting rubbery mass should be cut into small cubes and is ready for use. Heat, as before, until liquified and, after cooling somewhat, pour over the object to be cast. Harden the inner mold surface by coating with alum water before pouring hot wax into it. It may be used for casting objects in either wax or plaster.

Gelatin-Glycerine Solution for Water and Other Uses

To 1 lb. of gelatine add 1 qt. of water. When all water has been taken up, boil in double boiler until about 1 qt. of bulk remains. Add 13 fluid oz. of glycerine and 10 drops of carbolic acid. This solution should be made in advance of requirements, so that all water will have evaporated. It may then be flown over a glass base to give a water effect, or be flown into a mold which has been made from a surface representing disturbed water. This slab, when set, may be laid on a glass surface. In either case, the gelatine surface should be varnished when thoroughly set.

This solution may also be diluted for immersing leaves to be fastened to a Group base.

Glycerine Solution for Preserving Leaves, Branches, Grasses, Etc.

33 parts glycerine
2 parts formaline
65 parts water

Dextrine Maché for Modeling or Pointing up Tree Bark

4 measures Dextrine 4 measures cold water	boil
Add	
5 measures dry paper pulp	
1 measure manikin sawdust	
7 measures whiting 7 measures plaster	mixed thoroughly together first

The "set" may be varied by using more or less plaster.

In mixing plaster, fill the pan with water to about half the bulk of plaster required. Sift the plaster into this until it stands dry above the water level. Let stand until the whole is wet, then mix thoroughly with the hand until smooth and creamy. If too thin, the plaster will be weak; if too thick, it will not flow easily.

Never remove plaster from the object being cast until the mixture has become quite warm. At this point it has sufficient "set" to be removed without breaking.

Always wet a plaster surface where a fresh plaster coat is to be applied.

Metal Molds

Any metal casting process may be used for making metal molds, but it will suffice to give here one of the simpler methods.

First, make a plaster mold as already described. When this is thoroughly dry, build a dam close about the margin with molding sand, and pour heated type-metal over the mold surface. When cold, smoke the surface with a sooty deposit and enclose in a dam, as before. Pour metal onto this, and the result is two metal molds in perfect contact.

XX. Common Troubles and Their Causes

Leaves stick to the mold—
- Wax too hot
- Molds not thoroughly soaked

Leaves do not fill out—
- Too little wax
- Wet cotton

Leaves too thick—
- Too slow in closing clamp after pouring wax
- Wax too cold
- Mold too cold
- Wire rib out of midrib groove
- Midrib groove not deep enough for wire

Leaves tear easily—
- Too little cotton

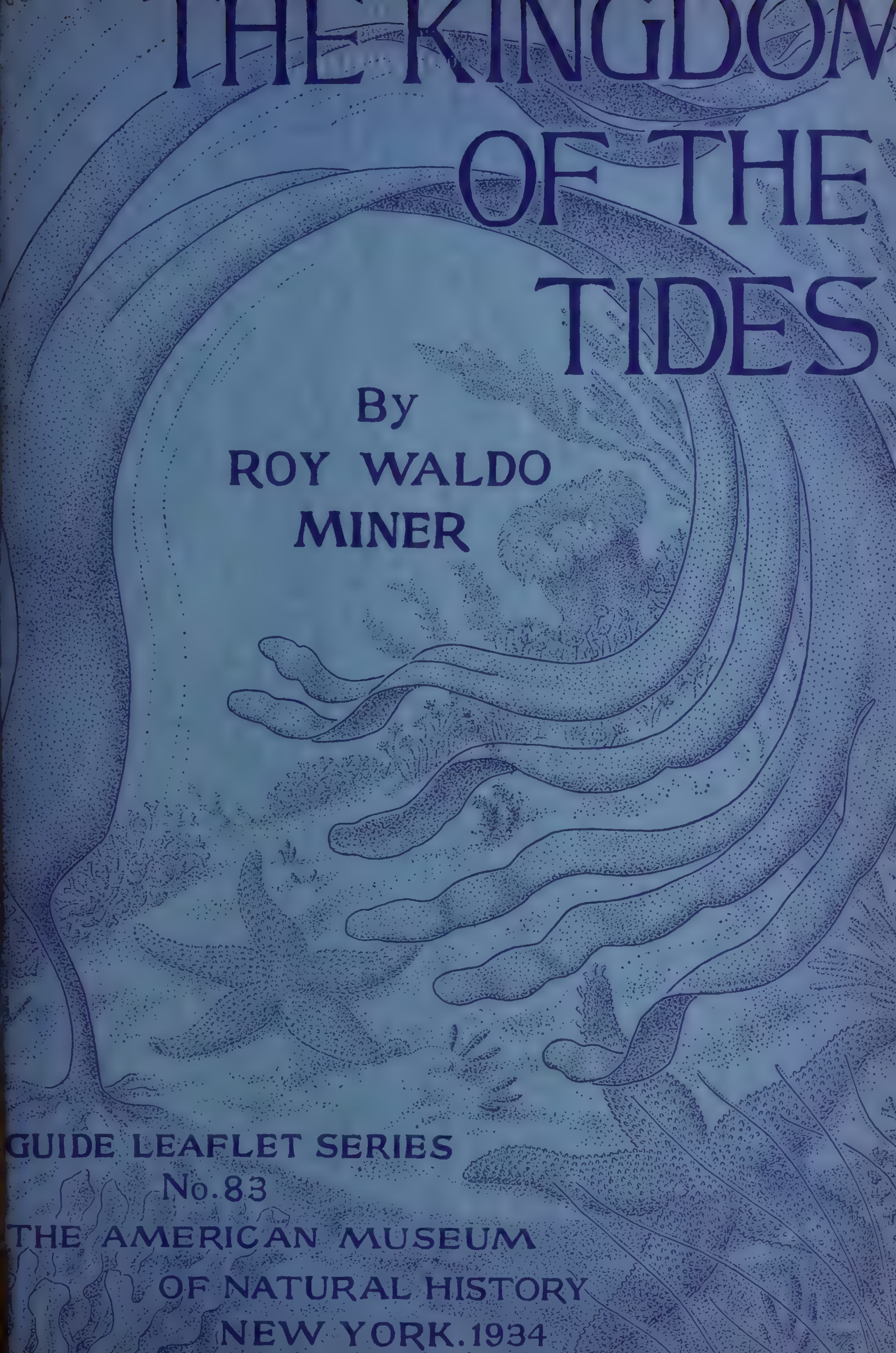
Leaves slip from midrib wire—
- Cotton on wire is wet
- Too little cotton on wire

Molds wear too fast—
- Not in alignment
- Soaking in too hot water
- Wax too hot.

XXI

Agar Agar	Any wholesale druggist
Air Brush	Spray Products Co., 756 Tenth Ave., New York City.
Burlap	Hoffman-Lion Mills, 542 West Broadway, New York City.
Calking Compound	Any building materials store.
Celluloid (Liquid)	Celluloid Corp., 290 Ferry St., Newark, N. J.
Celluloid (Sheet)	Celluloid Corp., 290 Ferry St., Newark, N. J.
Clay (Water)	Ettl Studios, 227 West 13th St., New York City.
Color (Dry)	Behlen Bros., 10 Christopher St., New York City.
Color (Oil)	Windsor Newton, at any artists' supply store.
Compressor and Tank Unit for Air Brush Work	General Air Brush Co., 129 Lexington Ave., New York City.
Cotton (Jewelers)	Dennison Mfg. Co., 220 Fifth Ave., New York City.
Cotton Flock	Mark Jacobs, 20 East 17th St., New York City.
Dextrine	Behlen Bros., 10 Christopher St. or Ehrmann-Strauss Co., 200 W. Houston St., New York City.
Duco Cement	Patterson Bros., 27 Park Row, New York City.
Formaline	Any drug store.
Glycerine	Wholesale drug store, for large quantity
Green Soap	Ehrmann-Strauss Co., 200 W. Houston St., New York City.
Paraffin	Asiatic Petroleum Co., 80 Broad St., New York City.
Plaster of Paris	Any building materials store.
Plasticene	Schneider & Co., 128 W. 68th St., New York City. or any artists' supply store.
Sand, Moulders	Any Bronze Foundry
Scissors	Kny-Scheerer Co., 21–27 Borden Ave., Long Island City, N. Y.
Silk Flock	Mark Jacobs, 20 E. 17th St., New York City.
Stearine	Ehrmann-Strauss Co., 200 W. Houston St., New York City.

Steel Dies	New York Die Co., 245 Centre St., New York City.
Steel Wax Tools	Ettl Studios, 227 W. 13th St., New York City.
Wax	Theo. Leonhard, Paterson, N. J.
Whiting	Behlen Bros., 10 Christopher St., New York City.
Wire (Galvanized)	Any hardware store.
Wire (Iron Mesh)	Estey Wire Works, 34 Cliff St., New York City.



THE KINGDOM OF THE TIDES

By
ROY WALDO MINER

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A STUDY IN LOCOMOTION AMONG MARINE ANIMALS

Detail of Wharf-Pile Group in the Darwin Hall of the American Museum

The stationary animals of the wharf piles are contrasted, on the one hand, with the jellyfish (*Dactylometra quinquecirra*), which swims aimlessly without power of direction, and on the other, with the squid (*Loligo pealii*) and cunner (*Tautogolabrus adspersus*), both of which possess highly coördinated and efficiently controlled swimming organs

The Kingdom of the Tides

Some of the Creatures One May Find along the Shore Line of New England

By
Roy Waldo Miner
Curator, Living Invertebrates
American Museum

WHEN we look at maps and charts, we see the boundary between land and sea marked by a definite line, but if we search for its exact location as we stroll along the beach, we cannot find it. The incoming waves rush up over the sands until they flatten out, lose their momentum, hesitate, and stream back into the flood whence they came. As the tide rises, the sea gradually advances farther inshore, but finally a limit is reached at high water. At certain seasons, and at times of storm, a greater area of land is covered, but the recession always takes place and the territory won by the ocean is abandoned, until, at the very lowest ebb, a strip of sea-bottom, in turn, is conquered by the land.

The strand slides under water at the same general slope, and, though diversified by sand bars and shoals, the sea-bottom sinks at a uniform rate, until, at a greater or less distance offshore, at a depth of about six hundred feet, it dives at a more rapid gradient into the depths of the sea. Here, at the edge of this steep slope, is the first indication of a line of separation. It is said that, ages ago, the real boundary of the land was to be found here, and the continents were much larger. Now the seas have flooded over the edges of this ancient land, forming a comparatively shallow border or rim, varying in width from thirty to one hundred miles, which we call the continental shelf.

This shallow area, well lighted by the sun, and warmer than the oceanic deeps, is the real theater of the life of the sea-bottom. In the sunlight the sea-plants, or algæ, abound, and feeding among them are myriads of small oceanic creatures, which, in turn, form the food of the larger inhabitants of the sea.

Here are gathered living hordes of fishes, mollusks, crustaceans, sea-worms, echinoderms, and the lower forms of life. From this shallow zone, in the course of time, many species have invaded the deeper waters and have become adapted for the dark abysses beyond the edge of the continental shelf. Myriads of others have crowded into the warm, sun-lit shallows near the shore and have even sought the intertidal stretch which is laid bare twice daily by the ebbing tide.

As we walk along the shore at low tide or wade in the shallows, we invade the edge of this teeming world of sea-creatures and see many signs of their activities. Along our coast from New York to the Bay of Fundy, the aspect of the ocean margin presents many contrasts. Long Island and Connecticut are characterized by stretches of exposed sand beaches, sheltered mud flats and sand spits. Here and there may be found out-croppings of rocks or tide-rips where glacial bowlders have been laid bare, but the chief character of the coast is low and free from rock. This condition becomes intensified as we reach and round the curving arm of Cape Cod, which is nothing but a huge sand spit. North of Massachusetts Bay and Boston, bold headlands of rocky cliff jut out into the sea, as at Nahant, Marblehead, Gloucester, and Cape Ann generally. Along the coast of Maine, high, rocky cliffs become the rule, lining and limiting deep bays, sown with jagged islands, and hemming in the estuaries of great rivers.

The height to which the tide may flow

Sea Shore Warfare

The five pictures at the right show, first, a colony of oysters on a mud flat. The second picture shows a mass of invading mussels which, in the third photograph, are pictured after they have overwhelmed the oysters. The fourth view depicts the mussel colony being invaded, in turn, by barnacles which, in the fifth view, are shown completely victorious





A barnacle extending its feathery feet from its limestone wigwam

Creatures of the Sandy Beach


At the left on the opposite page are two pictures of *Natica*, the sand collar snail, which hides in mound-shaped burrows or crawls over the sand, pushing its fleshy apron before it. Next comes a lady crab up to her eyes in sand; a "sand bug" preparing to "dig in"; a rock crab, and finally another lady crab showing its paddle-shaped hind legs

shows great variation. Along the exposed sandy shores of southern New England it ranges from two to five feet in height, except where the incoming seas are forced into narrowing bodies of water like Long Island Sound, where it rises six to seven feet, as at New Haven and Bridgeport.

High Tides and Low

On the outer side of Cape Cod, the rise is but two feet, but the masses of water that crowd into Cape Cod Bay reach nine feet at Plymouth. North of Boston this height continues, becoming gradually increased along the Maine coast. The Gulf of Maine is a huge, curving and tapering funnel, guarded by Cape Cod to the southward and the peninsula of Nova Scotia to the northeast.

The tides entering this huge gulf are shunted along the hollow curve of the Maine shore line and Bay of Fundy, rising at high water eighteen feet at Bar Harbor, twenty-eight feet at St. Andrews, New Brunswick, and the enormous height of forty-five feet during spring tides at Amherst and Truro, where, at the double apex of the funnel-shaped Bay, the Nova Scotian isthmus ties the peninsula of that name to the mainland of North America.

Naturally the combination of high, swift-running tides and rocky coasts has a far-reaching effect on the animal and plant life inhabiting the impetuous waters of northern New England, compared with the low-lying, quiet, sandy and muddy coasts of the more southerly portions.

The temperature of the waters in the two regions also is of great influence. Southern New England is washed by spurs from the warm waters of the Gulf Stream, especially in the Cape Cod region which, with the outlying Elizabeth Islands, as well as Marthas Vineyard and Nantucket, juts boldly out into the sea. But farther north, the cold Arctic Current pushes its way in close to the shore, and creatures which, in southerly waters, are found only in the deeper, colder seas, here occur near the surface and are able to live in shallow waters near the rocky shore.

If we could stroll along the entire New England coast in a few hours, we should find ourselves passing over regions continually changing in character, and the species of animals populating the shallow waters around the low-tide limit also would be seen to vary in harmony with the changing environment. The forces of inanimate nature sift out all individuals that invade regions to which their bodily structures and habits are not adapted.

As it is out of the question to cover so much territory in one journey, let us transport ourselves in imagination from place to place and sample a number of contrasting typical localities to become acquainted with the shallow-water animals characteristic of them.

An Exposed Sandy Beach

The white sand stretches out before us for miles, heaped high into dunes at our left or extending over into broad flats covered with beach grass and low shrubbery. At our right, the surf breaks thundering on the shore, washing to our very feet and bringing quantities of loose sand along with it. Here and there, with a rattle and a roar, the waves bombard the coast with masses of rounded pebbles, spreading them over the strand in assorted sizes ranging from gravel to bowlders.

We pick up dead and empty shells on the beach, many of them broken and beach-worn. Ruffled fronds of kelp are washed up and other flotsam from the sea, but, for the most part, life is conspicuous by its absence, and the sandy shore seems barren indeed. This is not to be wondered at. The shifting sand gives little opportunity for harboring animal life which otherwise might burrow within it, and the force of the waves transforms into grindstones the pebbles and rocks which, in quieter waters, would give

shelter to all sorts of sea-creatures. The siliceous sand grains are barren of food material and could support no life even if any could find foothold among them.

Nevertheless, at the upper tide limit, long lines of beach wrack mark the boundary of the ocean's surge, and as we stir up the decaying and drying fragments of seaweed, swarms of beach-fleas (*Orchestia agilis*) come to life and jump hither and thither in clouds. If we are quick, we can capture them and put them into a glass jar, where we can examine them at leisure. They are olive green in color. Now, as we look closely at the sand not far from the high-tide mark, struggling forms emerge from tiny little holes that are almost invisible, and go leaping about, their grayish, sand-colored bodies closely resembling their environment. They, too, are sand-fleas of two different species (*Talorchestia megalopthalma* and *longicornis*) somewhat larger than their green brethren and distinguished by unusually large eyes and long feelers, respectively.

The Lady Crab

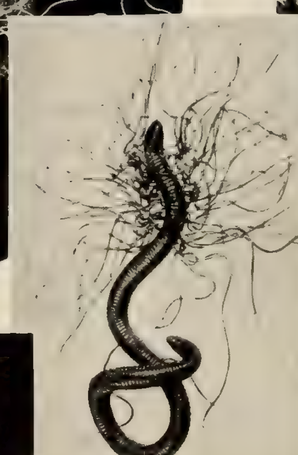
At low tide, when the sea is calm, one may wade in the shallows with a water glass and find other evidences of life. Yonder a lady crab (*Ovalipes ocellatus*) goes swimming by sidewise, waving its paddle-shaped hind legs over its back as a means of propulsion. A short distance away it settles down on the sea-bottom, raises its stalked eyes, and regards us warily. We approach with stealth, to get a good view of its carapace gayly spotted with irregular purplish pink dots, and the sharp pincer-like claws, striped also in purple and pink, which wave menacingly toward us. It is all a bluff! For as we cautiously wade nearer, the crab shoves the hinder margin of its carapace down into the sand, and rapidly digs itself under till only the frontal edge, the ends of the stalked eyes, and the waving, threadlike antennæ are visible.

The rock crab (*Cancer irroratus*) is also abundant here, scuttling over the sandy floor, as it has no paddles to swim with like its more fortunate cousin. We catch glimpses of the slender almost transparent boatlike bodies of the common shrimp (*Crangon vulgaris*) darting here and there like phantoms.

Sand-collar Snails

A number of sand-collar snails of two species (*Natica heros* and *duplicata*) have started a settlement yonder where the sandy floor is nearly level and is laid bare only at the lowest tide. Low, rounded mounds scattered over the wet sand betray their habitat, and, as we watch, there is a disturbance in one of them which is still under water, and we see a round, almost globular shell, about as large as a tennis ball, break through. A fleshy foot protrudes itself from the shell opening and extends forward and back over the sand until it seems impossible that so much animal could be packed so tightly within the spire of the shell. Now it begins to travel forward, pushing before it an apron-like flap, above which waves a pair of antennæ, each with an eye-spot at its base.

As the creature slowly progresses, a transparent, jelly-like ribbon emerges from under the right side of the apron and is slowly pushed around the lower margin of the shell, where it is overlapped by a fold of the broad, fleshy body. Soon it completely surrounds the shell like a border. The snail continues to creep forward and leaves the transparent ribbon behind it on the sandy sea-floor. The sand washes against it and sticks to it. We pick it up and find it is a delicate little collar-shaped arrangement, open in front and slightly ruffled at the lower margin. The sand which has stuck to the outer surface covers it in a single layer, giving it an appearance of fine sandpaper. If we examine the under side with a hand lens, we find that it is entirely lined with a

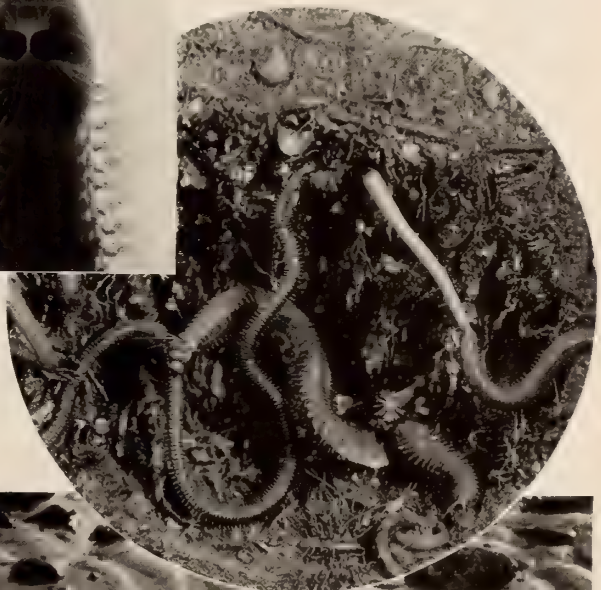


Tidal Water and Marsh Grass

In settings such as the one shown at the top of the page, fiddler crabs dig burrows among the grass roots. The sectional view above at the right shows a fiddler-crab burrow, together with a starfish preparing to feed on an oyster. Marvelously adorned seaworms dig in the mud, as well. In the circle the ornate worm (*Amphitrite ornata*) spreads its delicate tentacles; in the center rectangle a fringed worm (*Cirratulus grandis*) extends its threadlike filaments; at the left is pictured the head of a plumed worm (*Diopatra cuprea*). Except for the view at the top, these photographs are of models at the American Museum

A Ripple-Marked Mud Flat

Prolific sea worms make their homes and dig their subways in the tide-washed mud. In the circle, a clam worm (*Nereis*) appears to be attacking an opal worm. At the upper right a trumpet-worm model is shown, surrounded by the sand grains that it has built into a home. The center rectangle shows a model of the head of a "beak thrower," pictured also in the circle "throwing its beak." Below at the left the head of an opal worm is shown, gleaming with iridescent hues. The tracks shown crossing the ripple marks in the bottom picture have been made by black mud-snails



Photograph by M. C. Dickerson

delicate layer of transparent eggs, each like a tiny bead of jelly, all closely set together in a finely wrought mosaic. As the collar dries in the sun, it becomes so fragile that it crumbles to sand in our fingers.

We now turn our attention to the snail itself and see that it is rapidly creeping through the shallow water toward a group of little flattened sticks standing up from the sand at an abrupt angle. The snail seems much interested in them. As we examine them with attention we see that their sides are formed of two long, narrow, slightly curving shells which somewhat suggest the size and shape of the old-fashioned razor handle. We recognize the razor-shell clam (*Ensis directus*). The shells stand half-buried in the sand, showing the ends of their short siphon-tubes at the top bordered with fringelike papillæ. Apparently they are aware either of us or of the approaching snail, for suddenly first one, then another, shoots down into the sand until the siphon-openings are barely even with the surface. They are great diggers, for their lower end is equipped with a powerful curved and tapering foot, which is used as a very efficient digging organ.

These inhabitants of the exposed sandy beaches, together with certain others, such as the soft clam (*Mya arenaria*), the surf clam (*Spisula solidissima*), the "sand bug" (*Hippa talpoida*), the sand dollar (*Echinarachnius parma*), and a few sea-worms, are able to endure the difficult conditions of exposure to the open sea. Most of them also occur in the more sheltered regions described below, but they are the hardy explorers of the shallow seas, and form the scattered population of a region which is otherwise without abundant visible life.

Sheltered Sand and Mud Flats

As we walk along the beach, we may find our progress stopped by an inlet through which the tide flows into more sheltered waters. In such places the currents wash the sand and mud away from the bowlders embedded therein and much of the mud is carried into the sheltered waters of the bay, to be deposited upon its floor, mingled with sand to a greater or less degree.

Among the Eelgrass

This mud is filled with nutritive material in which eelgrass grows readily and which also provides sustenance for all sorts of burrowing sea animals, and many others which lurk among the weed. Hosts of tiny creatures grow on the eelgrass blades, hide under the stones in the bottom and edges of the tidal channel, and cling to the seaweeds growing in such places.

Depending on the amount of exposure to the open sea, the soil grades from gravel, through sand, sandy mud of various degrees of admixture, and pure mud, abounding in inhabitants which thrive best in each special environment as well as those ubiquitous creatures which range over the whole field.

The little hermit crabs (*Pagurus longicarpus*) are among the latter. These may be seen scuttling back and forth in shallow water. They are small shrimplike creatures with a pair of heavily armored, formidable claws and four spiny walking legs, but with a soft, tapering abdomen which is their weak point and is entirely unprotected. Attached to this are a few pairs of small holding claws. To make good their deficiency, the hermit crabs appropriate abandoned snail shells, backing their soft abdomen into the spiral chamber of the shell, into which it neatly fits. They hold the shell in place by gripping the central columella of the spire with their weak abdominal claws, and then boldly run around with their castles on their backs. If assailed by an enemy, they retreat within the shell, closing the opening with one of their large claws. However, certain species of fish eat them, shell

and all. The hermits are the scavengers of the shallow seas and always gather together in great numbers to feast upon dead and decaying plants and animals. On muddy bottoms they are joined by the black mud snails (*Nassa obsoleta*), whose progress over the mud can be traced by their undulating groovelike trails.

A Populous City on a Shell

The hermit crab is also interesting, because, in many cases, the dead shell that it carries may become covered with a soft substance appearing at first glance like the pile of coarse velvet. If we place such a crab in a small dish of sea water and look at it under a magnifying glass, this covering resolves itself into a city of tiny hydroids (*Hydractinia echinata*), little flower-like creatures with slender tube-shaped bodies, some of them with terminal mouths surrounded with grasping tentacles; others with no mouths but carrying quantities of egg-producing organs looking like tiny clusters of grapes; and still others near the edge of the shell with no mouths, but with their heads crowned with beadlike batteries of sting cells. Obviously this is a community of specialists, some members of which are the feeders for the colony, others, the reproducers and nursemaids, and the rest the fighters. Each has its special work to do. All the individuals are connected by a network of tubes, so that food may be supplied to the members that have no mouths by those which secure and digest it.

Larger species of hermits (*Pagurus bernhardus* and *pollicaris*) hide in the eelgrass, where also may be found the great whelks (*Fulgur canaliculata* and *carica*), which bear large, coiled shells on their backs with a pointed siphon in front. The females of these whelks manufacture egg-strings, two or more feet in length, looking like strings of spiny, yellow pill boxes, in which the eggs hatch into baby snails with tiny shells like those of their parents. After a time the little snails emerge from a hole in the edge of each pill box and take up an independent life. The whelks prowl around, in the hope of capturing one of the scallops (*Pecten gibbus*) which abound in the eelgrass. This is a game of stalking, for the latter possess a hundred or more gleaming, steely blue eyes around the edge of the mantles, and, when alarmed by a shadow, will spring up in the water and flit out of the way, opening and closing their shells rapidly as a means of locomotion.

The green crab (*Carcinides mænas*), conspicuous with its bright green, yellow, and black markings, and the blue crab (*Callinectes sapidus*), familiar to us in the markets, frequent the sheltered mud flats in shallow water, while the small mud crabs (*Panopeus herbstii* and *sayi*) with their black-fingered claws are everywhere at the water's edge. The large spider crabs (*Libinia emarginata* and *dubia*), with their long legs and small, spiny, rounded carapaces, hide in the eelgrass and are hard to see on muddy bottoms.

Oysters and Mussels

On mud-flats laid bare at low tides one may chance upon occasional oyster beds, though these are usually cultivated at some depth. More frequently huge flats may be covered with edible mussels (*Mytilus edulis*). These black mussels are a potential article of food, now much neglected, but, when properly prepared, they rival the succulent oyster and little-neck clam in delicacy of flavor and nutritious value. On Marthas Vineyard Island, literally acres of mussels are laid bare at low tide. They multiply so rapidly that, if by chance they come in contact with a bed of oysters, they will overspread it and completely smother it. The rock barnacles, in turn, reproduce even faster than the mussels, and, by sheer force of numbers, given an opportunity, will invade a mussel colony and overwhelm it,

Above: A giant whelk pursues a scallop, which swims by opening and closing its shell

Below: The "velvet" on the hermit crab's appropriated shell is shown, in an American Museum model, to be made of three types of tiny hydroids—fighters, feeders, and egg producers

Above: A hermit crab in his borrowed and "velvet"-covered shell

Below: The familiar edible blue crab

Photograph by M. C. D[illegible]

Photographs,
M. C. Dickerson

Above: The green crab above is not edible, but is a pugnacious fighter

Below:
A spider crab, which has camouflaged himself by plucking tufts of Bugula and placing them on his back

A rough-spined spider crab, which has lost one claw

Below: A lady crab is shown swimming vigorously in an attempt to escape from a lobster

thus rendering poetic justice to the former conquering horde.

Enemies of Mollusks

These beds of shellfish, of course, attract the enemies of bivalve mollusks in great abundance. The most important of these are the oyster drill (*Urosalpinx cinerea*) and the common sea stars (*Asterias vulgaris* and *forbesi*). The former bores neat little pinholes in an oyster shell, and sucks out the contents, while the latter mounts the oyster, applies the pneumatic disks of its tube-feet to the two valves, and, bracing the tips of its arms against surrounding objects, pulls the shells open by main force and proceeds to devour their contents.

The oysters are not naturally found in muddy localities, but have been transplanted there by man, by spreading shells to form a "clutch." They belong more properly on a rocky bottom.

The animals most typically associated with more or less muddy regions are the sea worms. Burrowing in the soil everywhere, they construct tubes of greater or less consistency, or, in some cases, no tubes at all. They hide under flat stones, or dig among the roots of eelgrass. In localities rich in mud the fringed worm (*Cirratulus grandis*) burrows in great abundance, its reddish body adorned with a multiplicity of long, threadlike, breathing organs on the forward third of its body, each filament of golden yellow with a brilliant red thread of blood showing through the translucent walls. The plumed worm (*Diopatra cupræa*) constructs tough, parchment-like tubes in sandy mud, showing like chimneys above the sea-bottom, to which bits of shell and seaweed are cemented. The worm has a bluish iridescent body equipped on the forward part with marvelous blood-red plumes with spirally arranged branches. The ornate worm (*Amphitrite ornata*) builds tubes of sand and mud. It is a wonderful creature with three pairs of intricately branched gill-plumes on its shoulders and numerous flesh-colored tentacles extending in all directions from its head. Its body is beautifully marked with reddish brown, and a broadly tapering upper lip is colored from rich rose to violet. The opal worm (*Arabella opalina*) has an orange head with four eyes, and a long, slender body composed of brilliantly opalescent rings. The trumpet worm (*Pectinaria belgica*) digs with a pair of golden combs and constructs a trumpet-shaped tube of neatly matched sand grains arranged in a delicate mosaic.

Scores of other species occur, all remarkable for beauty, grotesqueness, or strange habits, but it is impossible to mention them all here. Needless to say, the sheltered mud- and sand-flat is one of the most fruitful fields for the study of the strange creatures of the sea.

Rocky Shores and High Tides

Let us now transport ourselves to the north shore of Massachusetts or the coast of Maine. We are on a rock-bound coast, hemmed in by high cliffs, against the base of which the incoming tide breaks in masses of foam, which scour through every crevice and rush back into the sea. The tide rises and falls nine feet or more, according to the locality, and, farther north, several times that distance.

At low tide the vertical walls of the cliffs are seen to be broken into shelving terraces, draped and festooned with rockweed, bordered above with a long frieze of white barnacles. The basin-like hollows on the rocky terraces are filled with water, even when the tide is at its lowest, and each one glows with submerged colors like an aquatic sea-garden. There is no soil for burrowing like that on sand- and mud-flats, and all animals having no adequate clinging organs, or requiring a soft substratum for burrowing are eliminated here by the force of the elements, and yet

Left: The only coral (*Astrangia danaë*) of the New England coast is shown growing over a rocky bottom

Photographs, M. C. Dickerson

In the small rectangle a common starfish (*Asterias vulgaris*) is portrayed. *Below:* A starfish is shown attacking a small fish. The "tube-feet" are equipped with sucking discs by means of which the fish is dragged into its attacker's central mouth

Above: A sea anemone (*Metridium marginatum*) expands its feathery crown, which is armed with sting-cells with which it slays small fish for food

The rocky coast at low tide. The white band is made up of barnacles. Below these, festoons of rock weed partly cover crowded masses of mussels. In the water, starfish and green sea urchins abound

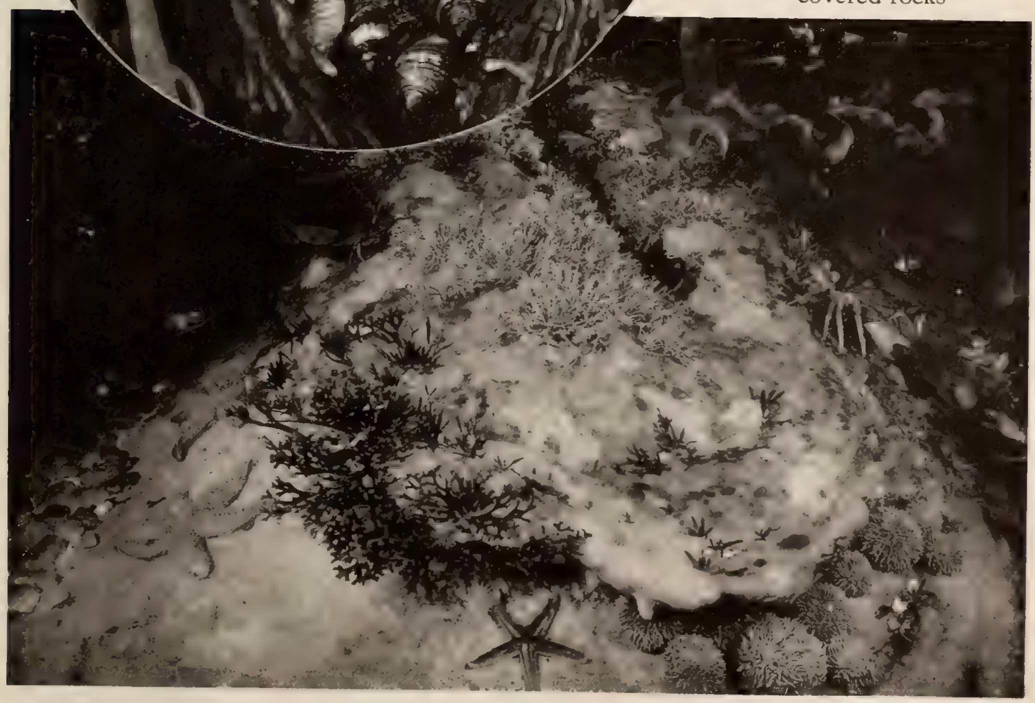
Right: The little red sea star (*Henricia sanguinolenta*), which is abundant in the tide pools of rocky coasts. Photograph by M. C. Dickerson

Below: A view looking through the clear water of a pool replete with Irish moss, coralline dulse, kelp, rockweed, and sponges

Seaweed drapes the rocks of a beautiful pool at Nahant, Massachusetts. In these clear, quiet waters are displayed a magnificent sea garden in which the observer may find a rich field for observation

Left: Purple snails (*Thais lapillus*) are shown feasting on mussels. These snails produce a beautiful purple dye similar to the ancient Tyrian purple. A cluster of eggs is also visible

Below: A corner of the Nahant pool showing green sea urchins, sea stars, and green crabs on the coralline covered rocks



certain creatures familiar to the southern shores adapt themselves to these trying conditions and survive.

Black Mussels and Purple Snails

The same kind of black mussel (*Mytilus edulis*) that covers the mud-flats of the southern coast to so great an extent, clings to the rocks in broad bands below the barnacle zone and underneath the rockweed, but, in exposed situations, the shells are always very small, for when they reach a size to present resistance to the force of the waves, the silken strands of their tough byssus threads give way and they are stripped from their anchorage by the rushing water. They also must dispute their territory with the purple snails (*Thais lapillus*), which cluster in numerous colonies and feed on the little mussels. These snails derive their name from the fact that they exude a purple fluid, allied to the Tyrian purple of Mediterranean snails. Their shells, however, are gayly banded with red or yellow spirals, or the entire shell may vary from white, through orange, red, and brown. They lay their eggs in little pink or yellowish vase-shaped capsules, which stand on slender stems and are grouped together in small patches in the crevices of the rocks.

At low tide multitudes of sea stars familiar to the southern shore (*Asterias vulgaris*) but varying greatly in color from purple, through blue, crimson, and yellow, feed on the mussels and on the little green sea urchin with the long scientific name (*Strongylocentrotus droehbachiensis*), which is very abundant here. Another sea star characteristic of rocky coasts is a small, deep-red species (*Henricia sanguinolenta*), bright yellow beneath and at the tips of its curving arms. The Jonah crab (*Cancer borealis*) is very common, crouching and hiding in rocky dens. It is larger and with much rougher carapace than the rock crab of Southern New England (*Cancer irroratus*), which also is found on the northern coast, but more sparingly.

The tide pools on the terraces show remarkable concentrations of sea life. As the sun slants through one of these flooded basins at low tide, it lights up tangles of rich brown, brilliant green, purple, pink, and red algæ, their graceful fronds clustering and overarching miniature vistas, in which acorn snails (*Littorina litorea*), green crabs (*Carcinides mænas*), and tiny red or variegated chitons (*Chiton ruber* and *apiculatus*) creep about amid fairy clusters of pink-hearted hydroids (*Tubularia crocea*), gray-green chimney sponges (*Halichondria panicea*), and pink finger sponges (*Chalina oculata*).

Sea Anemones and Seaweeds

Sea anemones (*Metridium dianthus*) expand their broad, flower-like, fringed disks, and cylindrical bodies, brown, pink and white, and bright orange in color. Even the rocky basin itself is enameled with encrustations of red-purple *Melobesia* and brick-red *Lithothamnion*,—calcareous seaweeds, that spread thin, stony layers of color over the underlying rock. Clusters of huge horse-mussels (*Modiola modiola*) covered with purple and red bryozoa, open their shells slightly, exposing their orange-colored mantles.

It seems impossible that there should be such an abundant association of living forms in so small a space, but the secret lies in the flood of aërated and food-laden waters that twice a day overwhelms these tidal pools and brings the inhabitants everything on which their life depends.

These associations of the animal life of the seas, whether on sandy shore, mud-flat, or rock-bound coast, are but glimpses of an almost infinite kingdom of creatures under the rule of the tide, which sweeps over the great oceanic shelf, bringing life or death to its subjects, depending upon how they adapt themselves to its laws.

JADE, AMBER, AND IVORY

By HERBERT P. WHITLOCK

Curator of Minerals and Gems, American Museum

Reprinted from Natural History Magazine
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26 Photographs by the American Museum Staff Photographers

Precious and beautiful carvings of the Drummond Collection depicting not only the art, but also the ancient myths and legends of China and Japan

AMONG the court officials who attended the Chinese emperors of the Chou dynasty (B.C. 1122–255) there was, it is said, a steward of the treasury whose task it was to attend to the preservation of the Hall of the Ancestor of the Imperial House, in which were kept all the precious objects handed down from generation to generation. This stewardship of the treasury, however, has long since been abolished. Even the latest dynasty of Chinese emperors has passed away and with it much of the tradition and romance that are always attached to what is old and what is regal. Yet, although there is no longer an imperial treasury in Peiping, there has been created during the past six months, in the American Museum in New York, a veritable "Hall of Ancestors," a treasure house in which are gathered the beautiful and precious objects representative of Chinese and Japanese culture brought together through the life work of a man whose knowledge and taste in these matters rendered him an authority of high standing.

This new acquisition of the American Museum is the collection of the late Dr. I. Wyman Drummond, which came to the Museum through the gift of his sister, Mrs. Katherine W. D. Herbert. In reality it is not merely a collection. Instead, it is a group of collections, each correlated with and supplementing the others; and with so keen an appreciation and such ripened knowledge have these units been chosen, that it seems as though the touch of beauty passing from hard, cold jade to glowing amber and vitalized ivory, carries with it all the wealth of tradition and symbolism of the two great oriental races.

In the matter of jade alone the Drummond Collection, which is now the Drummond Memorial, is a rich and well balanced series, representative of all periods, and covering a cultural range of more than thirty centuries. Exceptional indeed is the splendid group of ancient jade ceremonial weapons which has no counterpart in other museums of the world. By far the most important piece in the series of carved jade, however, is the superb composite piece of white jade that constituted the gift to the Emperor Kien lung by the officials of his court upon the event of his fiftieth birthday.

In solving the problem of the display of the Drummond Memorial in the round tower room at the southwest corner of the fourth floor of the American Museum, this famous piece of jade has been made the center of the installation. From it, like the spokes of a wheel, radiate the eight upright cases, some of which are equipped with glass shelves, while others are treated in panel fashion.

The left half of the room is devoted to jade arranged by periods, and the right half is given over to amber, ivory, lacquer, and bronze sword guards. Around the walls between the window spaces are ranged the cabinets which contain the units of the Drummond Collection as they were formerly displayed at Doctor Drummond's residence. With these latter cases care has been taken to retain the original arrangement, so that every piece occupies exactly the position with respect to its neighbors that it did in the

The ivory statuette of K'wan Yin of the Fish is characteristically Japanese both in conception and rendering. It immortalizes in ivory the story of the princely fisherman who set up a shrine to this goddess after her image had repeatedly appeared in his net, taking the place of the fish he sought

K'wan Yin
of the Fish

Japanese Figures

Left:—A miniature carving in ivory of the celebrated Buddha of Kamakara sitting in eternal meditation. Behind the master spread the wonderful conventionalized flames symbolizing purification

Above:—An elaborately carved ivory figure of K'wan Yin, the Goddess of Mercy, holding a vase which is one of the traditional objects associated with her. The wealth of detail and marked realism of this Japanese figurine is in strong contrast with the formal conventionality that stamps the Chinese rendition of such a subject

Left:—A charming and elaborately wrought figure of Lan Ts'ai-Ho, the work of a Japanese ivory-carver. Lan Ts'ai-Ho was one of the Taoist immortals who wandered through the streets singing of the futility of earthly pleasures

Carved In Ivory

Right
Wang Mu, the Chinese Queen of the Fairies, attended by one of her jewel maidens, who holds a basket filled with the immortal peaches. A very charming little group in Japanese carved ivory

Left
The Three Heroes of Han, legendary Chinese warriors of the Han dynasty (200 B.C. to 250 A.D.). They are represented in this ivory carving as drinking *sake* in a kind of Japanese Valhalla

Chinese and Japanese Ivory

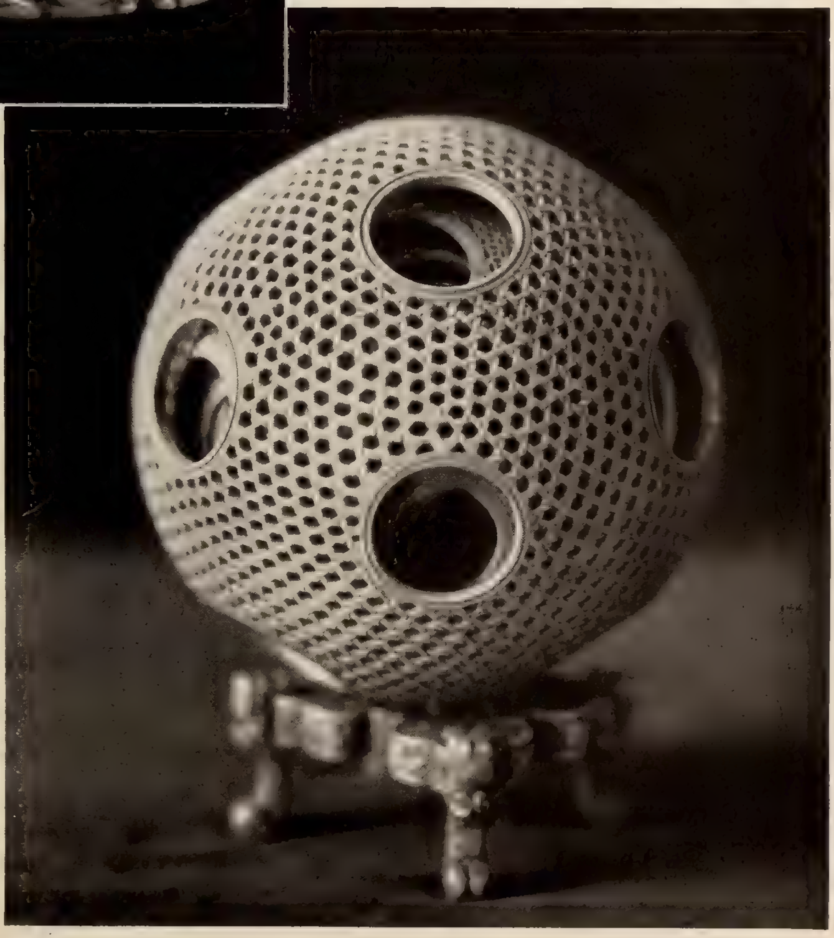
Left:—This intricate Japanese carving in ivory represents the Dragon Boat, laden with immortals and magical treasures. It is being guided to the Western Paradise by the crane, the messenger of the gods

Below:—The reverse of the group representing the Chinese Zodiac pictured at the left of the opposite page

Above:—Among the outlandish animals originating in Chinese mythology, one of the strangest is the Baku, the creature that feeds upon the bad dreams of mortals. This Baku is carved from ivory by a Japanese artist

Right:—The miniature figure of Ho Hsien-ku (only three inches high) is carved from ivory and dark wood. She is supposed to have lived in the Seventh Century, and, having attained immortality, became a fairy. In her hand she carries a fly whisk

Above:—This little masterpiece in ivory pictures a realistic group of the twelve creatures (the back of the group is shown on the opposite page) that represent the Twelve Terrestrial Branches, the Chinese zodiac. As seen they are the dragon, the rat, the cock, the monkey, the ox, the serpent, the goat, and the dog



The carving of a "puzzle ball," such as this one, is a feat of ivory carving performed only by Chinese artists. Carved from a single piece of ivory, this ball incloses eight others, each smaller than and separated from the next outer one

lifetime of this famous connoisseur, the charming taste and sense of color that have always characterized his displayed collection thus being retained.

Particularly is this the case with the series illustrating the various colors of jade of relatively modern date, which includes among others the rare lavender tint very much prized among collectors.

The magnificent suite of Burmese amber, which also speaks eloquently of Doctor Drummond's taste in color arrangement, has been conceded to be the finest assemblage of oriental amber in the world. Here ruby-red colors contrast with limpid honey-yellow and mottled orange in wonderful and intricate carvings.

Of the six wall cases that contain the varied and important collection of Chinese snuff bottles, one is filled with those fashioned almost exclusively of oriental amber.

Jade

Perhaps no one material other than jade can turn back so successfully the pages of time and permit us to read the record of a culture that was old when our own was struggling to emerge out of barbarism. Here, among these old jade objects, many of which have been buried for centuries, we find the beginnings of a philosophy, cosmic in its inception, that in China has outlasted dynasties.

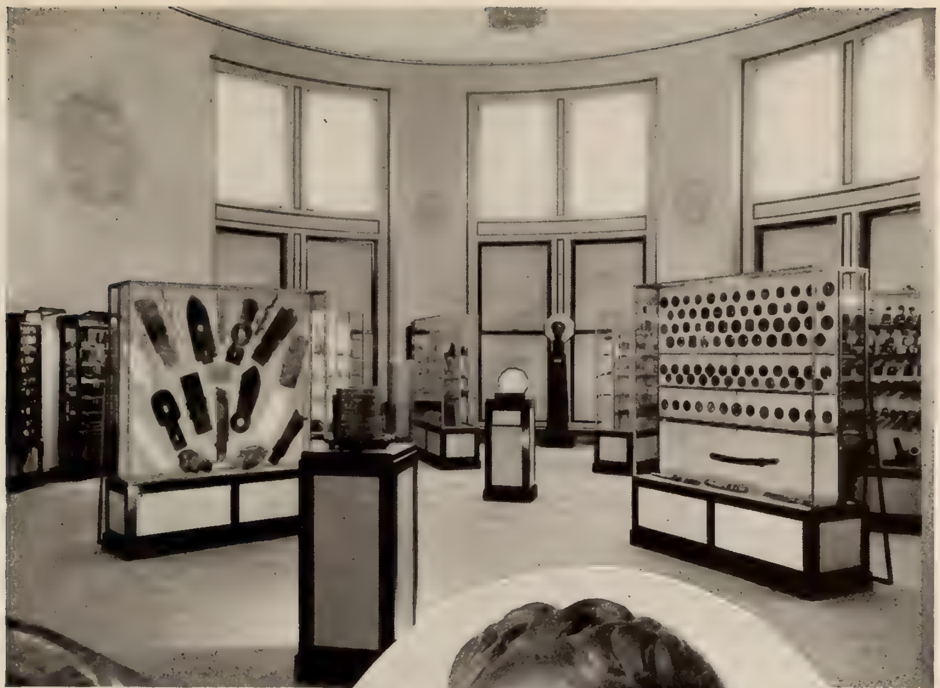
Among the most ancient of the symbols carved in antique jade is the group of designs called the Twelve Ornaments. More than 2000 years B.C. the Emperor Shun, referring to these designs, said, "I wish to see the emblematic figures of the ancients embroidered in five colors to decorate the official robes." Only the Emperor had the right to wear the complete set of twelve emblems on his ceremonial robes. Nobles of the first rank were restricted from using the symbols of the highest order. With decreasing rank further restrictions in the display of the remaining nine ornaments defined five sets of official robes. In the Drummond Collection an ancient and beautifully carved jade piece, representing the deity Earth, expressed by the Chinese as being square outside and round inside, represents on one of its faces these ancient Twelve Ornaments.

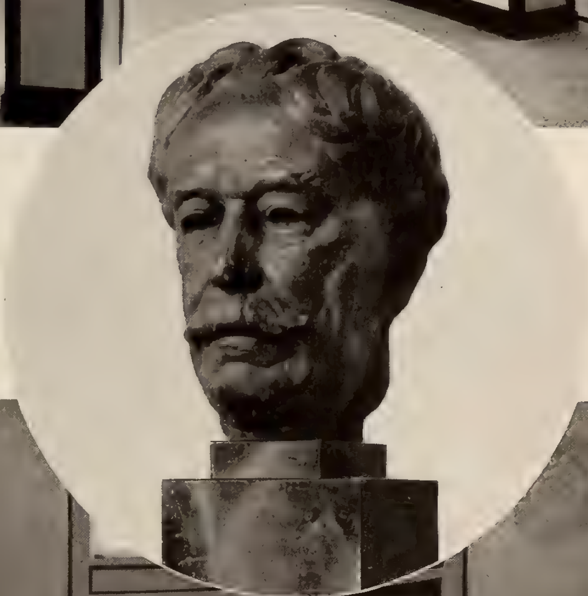
A very fine piece of white jade of the Kien lung period of renaissance in glyptic art is in the form of a "Scepter of Good Luck" (Joo-i scepter). On the long handle of this piece are carved in high relief the figures of the Eight Immortals, the half mythical, half historical personages so often represented in Taoist art. Each of these carries some characteristic object, such as the flute of Han Hsiang-tzu, whose marvelous tone caused flowers to grow and blossom instantly.

Singularly enough, there is, in the Drummond Collection, a Chinese flute carved from pure white jade, and while those of us who were privileged to hear M. Georges Barrère play upon it at the opening of the Drummond Hall, might need to stretch our imaginations a little in order to credit it with causing the spring flowers to bloom, it nevertheless has a remarkable tone, quite capable of producing exquisite music. Incidentally, it was made in 1488 in the Studio of the Eternal Spring. Many symbolic designs, have, through the reverence that all Chinese have for what is old and traditional, persisted throughout jade and amber carvings down to the present day. (See the author's article on "Jade" in NATURAL HISTORY for September-October, 1932.)

Japanese Carvings

In sharp contrast to the conventional treatment and traditional recurrence of designs in Chinese carving, is the realistic freedom that characterizes the work of Japanese carvers in ivory and wood, scores of examples of which are included in the Drummond Collection. Hampered by no such formalism as that which has been handed down through generations of Chinese lapidaries, the Japanese artists, working in ivory, produce graceful and impressive figures of the sages and immortals, charming and often grotesque statuettes,





Above:—A general view of the Drummond Hall

Circle:—A portrait head of the late Doctor Drummond, modeled by James Drummond Herbert

Below:—In the center stands the assemblage of jade pieces which was presented to the Chinese emperor Kien lung on his fiftieth birthday

Jade

and

Amber

This white jade incense burner is a superb example of the open work carving that reached its height in Kien lung's time. Both the bowl and the cover were reduced to about the thickness of a piece of heavy cardboard before the intricate lacelike pattern was executed with hundreds of

The dragons on this jade cup are of the form which developed in China in the Ming dynasty. The perfection in carving, however, shows the piece to be of later date, probably early Kien lung

Of a wonderful rich orange is this piece of Burmese amber carved to resemble a huge peach, to which is added the "long life" symbol, showing that it is a "Peach of Immortality." Two bats, signifying happiness, flutter above

An Emperor's Birthday Gift

A masterpiece of modern carving in white jade was selected for this gift to a famous emperor—Kien lung. The central piece has a loose button decorated with the *yang yin* (universal life symbol). Surrounding the central piece are twelve pieces fitted together, each of which is carved with a representation of one of the twelve creatures which in China correspond to the signs of the zodiac as used by Westerners

A very ancient jade image of the deity Earth carved with representations of the Twelve Ornaments. Reading from the top downward these are: The sun, the moon, the stars, mountains, dragon, pheasant, the cups, pond weed, fire, grain, the axe, and the symbol of distinction. The Twelve Ornaments are of great antiquity and signified authority and power

Highly conventionalized dragons as well as a bat meaning happiness mark this elaborately carved disk of white jade

Sword Guards

A magnificent gold dragon decorates this Japanese sword guard, and since this is a "dragon of the air" he is surrounded by conventional clouds

The subject pictured on this sword guard in bronze of various colors and in gold inlay is from the Japanese fairy tale of the sparrows who entertained their human friend in a manner singularly human, even for fairy-tale sparrows

The maker of this magnificent Japanese sword guard chose for his subject the fairy tale that recounts the adventures of Momotaro, who, with the aid of a dog, a monkey, and a pheasant, overcame the demons and took their treasure for ransom

A Traveling Shrine

This lacquered box is in reality a traveling shrine. The wooden interior displays a figure of Amitabha, the Buddha of Enlightenment, beautifully carved and gilded

A Crystal Snuff Bottle

Among the almost miraculous feats of dexterity practiced by Chinese artists is that of painting the *inside* surface of a glass or rock crystal snuff bottle. This delightful little painting was executed by passing a very minute brush through the neck of the bottle and reversing the strokes, somewhat in the manner of a "looking-glass" painting

and groups illustrating folk lore and legend dear to the hearts of Japanese boys and girls.

Among the ivory figures of appealing beauty from the Drummond Collection, is the "K'wan Yin of the Fish" in which the goddesss is poised with great freedom of action upon the back of a huge carp. The legend that inspired this masterpiece relates how a banished Japanese prince, who was forced to earn his living by fishing, on one occasion found in his net no fish but instead a small image of the Goddess of Mercy. This he threw back into the sea only to find it again when he next cast his net. So he kept the image and with his own hands fashioned a shrine for it on a hill overlooking the sea, where the Goddess of the Fish was continually worshiped.

Another charming figurine to which a story is attached, is Hsi Wang Mu, the Chinese Queen of the Fairies, whose legend, like many other Taoist myths, was brought into Japan from China. It is said that the palace of Wang Mu is in the Kuen-lun Mountains, where she guards the Tree of Immortal Peaches that grows beside the Lake of Gems, whose fruit ripens upon her birthday, every 3000 years. Here gather to the Feast of Peaches all the immortals to renew their immortality by eating the celestial fruit.

Carving in Ivory

A small but extremely intricate ivory carving shows the Dragon Boat laden with sages and immortals and freighted with the fabulous treasures of Takaramono, which include the hat of invisibility, the purse whose wealth never fails, not to mention many other remarkable things. Above flies the crane, the messenger of the gods guiding the vessel to the Western Paradise. With such wealth of detail are all of these ivory pieces wrought that such matters as necklaces and headdresses are rendered with the greatest fidelity. In fact, whole costumes might be copied to the last clasp and fold from these authentic sources. And such costumes! It would seem as though the devine K'wan Yin, and Lan Ts' ai-Ho, the immortal flower girl, were especially created to grace costume balls and pageants.

Sword Guards

Much as the Japanese carver in ivory loved to draw his subjects from the legends and myths of Japan, he was probably no match in this respect for his brother craftsman whose art consisted in fashioning sword guards from iron, bronze, and other alloys, some of which are not used outside of Japan. These were inlaid in gold and silver with great skill and artistry. A large and very handsome example from the Drummond Collection depicts an incident from the fairy tale of Monotaro, the boy who was found inside a peach, and who grew to be a sort of Japanese "Jack the Giant Killer." Accompanied by a dog, a monkey, and a pheasant, he invaded the island of the devils and, having overcome them in battle, returned to his astonished foster parents with all of their fabulous treasure.

Another beautifully inlaid sword guard illustrates the fairy tale of "The Tongue-cut Sparrow" who, after sumptuously entertaining his benefactors with food and *sake*, rewarded them for their charitable deeds with a basket filled with treasure. Needless to say the spirited designs which picture these folk tales are wrought by master artists whose names inscribed on little gold inlaid plates actually add to the attractiveness of their designs.

In order to describe in detail the hundreds of works of art that make up this extraordinary collection, one would almost require the magic aid of the gods and devils that are so generously portrayed among them. Nor, even then, could words picture these beautiful objects satisfactorily. Color, form, patina, subject matter—all require first-hand visual examination, before their beauty and their rarity can be made manifest.

They are, however, now on permanent display, and are ready, always, to offer their beauty to any who care to see.